CONTENTS

Contents ......................................................................................................................... 3
Preface ............................................................................................................................. 7

AVOCAAD
Johan Verbeke, Tom Provoost, Johan Verleye, Koenraad Nys,
Rob van Zutphen, Henri Achten, Gernot Pittioni, Alexander Asanowicz,
Adam Jakimowicz, Jonas af Klercker ................................................................. 9

Invited Speakers

Drawing, Seeing and Reasoning: the Added Value of Computer Aided Architectural Design
Mark Gross .................................................................................................................. 25

Towards the Post Digital Era
John Frazier ............................................................................................................... 35

Mediation
Ben Van Berkel ......................................................................................................... 41

Conference papers

A Collectively Designed Information Landscape
Maia Engeli, Malgorzatha Miskiewicz-Bugajski ...................................................... 47

An Environment for Collaborative Three-dimensional Modelling over the Internet
Kai Strehlke .................................................................................................................. 61

Automation of Deck Bridges Representations
Alcina Zita Sampaio .................................................................................................... 69

AVOCAAD exercises: Expanding on Facility Management
Daniel Oswald, Gernot Pittioni .................................................................................. 81

AVOCAAD exercises: Expanding on Interactive Operations
Martin Sprekelsen, Gernot Pittioni ............................................................................ 89

AVOCAAD exercises: Testing by Emphasising on Practical Features
Helga Rosenbauer, Carena Dallabetta ....................................................................... 95

Benefits of Data Integration in Building Modelling: 3D Object Oriented Professional Collaboration
Jen Kokosalakis, L.M. Hohmann, I. Pamplin, ‘The User Group’ ......................... 103
Computer in Creation of Architectural Form  
Alexander Asanowicz ................................................................. 131

Computerised Simulation to Urbanism Phenomena  
Ruthie Orev ................................................................................. 143

Creative Design in Object Oriented CAD Environments  
Zenon Rychter ............................................................................. 157

Creativity and Modularity in Architecture  
Leonardo Combes, A. Bellomio ..................................................... 169

Evocation and Serendipity in a CyberReal World  
Martijn Stellingwerff ................................................................. 181

Formulating a Computer Aided Architectural Design (CAAD) Program Model  
In Distance Education (DE) at Open Universities (OU):  
A study into an effective Integration of CAAD into Distance Education  
Ra’Ed QaQish, Khaled Tarazi ......................................................... 189

Modular Architectural Groupings from Escher Periodic Tessellations  
Roberto Hugo Serrentino ......................................................... 205

The Architect, CAD and Teaching: The Pedagogical Point of View at Tournai’s ISA Saint-Luc  
Jean-Pierre Couwenbergh, A. Croegaert, Benoit Gallez, P. Petit, M. Tilman 221

Rapid Prototyping Based Design  
Alvise Simondetti ......................................................................... 229

Some Experiences about CAAD on Design and Documentation Processes  
Ricardo Cuberos Mejia ............................................................... 237

The DIGITAL SKETCH Workshop: a Core Course in Design with Computation  
Reed Kram .................................................................................. 251

The Electronic Communication as a part of CAAD Educational Process  
Mirjana Devetakovic, Milan Radiojevic ........................................ 265

The Web to Support Creative Design in Architecture  
R. Corrao, G. Fulantelli .............................................................. 275

Transducer, 3D Audio-Visual Form-Making as Performance  
Reed Kram; John Maeda ............................................................ 285

User Defined Design-Generators – a Grammar Extension of CAAD Systems  
Michael Hellgardt ..................................................................... 293

Using an Immersive Virtual Reality System for Spatial Design  
Dirk Donath, Holger Regenbrecht .............................................. 307
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Design for Innovative Timber Structures</td>
<td>Rodrigo García Alvarado, Ricardo Hempel Holzapfel, Juan Carlos Parra</td>
<td>319</td>
</tr>
<tr>
<td>Virtual Reality in Early Design: the Design Studio Experiences</td>
<td>Henri Achten, Arthur Turksma</td>
<td>327</td>
</tr>
<tr>
<td>When Reality Fills Fantasy</td>
<td>Rob van Helvoort</td>
<td>337</td>
</tr>
<tr>
<td><strong>Workshop Morphogenetic Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Representing Floorplans for Interactive Evolutionary Design</td>
<td>H.P.S. Snijder, R. Daru</td>
<td>343</td>
</tr>
<tr>
<td>Discovering Theory</td>
<td>John Carp</td>
<td>347</td>
</tr>
<tr>
<td>The future of Evolutionary Design Research</td>
<td>Peter J. Bentley</td>
<td>349</td>
</tr>
<tr>
<td>Überblick - die in den vorstudien entstandenen Strukturen</td>
<td>Lenhart</td>
<td>351</td>
</tr>
<tr>
<td>Contribution to discussion</td>
<td>Celestino Soddu, Enrica Colabella</td>
<td>353</td>
</tr>
</tbody>
</table>
When, in November 1996, we received approval of our application (submitted exactly 3 years ago in March 1996) for a Leonardo da Vinci pilot project AVOCAAD (Added Value of Computer Aided Architectural Design), we could not imagine our current situation. Of course, we had a working plan. However, during a lot of meetings the theme AVOCAAD was discussed, explored and extended, finally resulting in the current AVOCAAD web-site containing almost 100 exercises. As a result we now have an ongoing extension and grouping together of CAAD teaching materials. Everything is accessible through a normal web-browser.

In April 1997 the project started with an International Conference and a partner meeting. Since then we had a lot of discussion and interaction. Later on, we extensively discussed our curricula and courses. As a result, I can state we now really have an good AVOCAAD partner group. I want to thank all partners for their stimulating discussions and contributions. It is due to this group and the work of the people involved, that we have realized a nice AVOCAAD product. This is explained in the first paper of this book.

Now, the moment has come to start extending the AVOCAAD group with other teachers and universities interested in the outcomes of the AVOCAAD pilot project. It is the intention of the partnership to make this possible in a structured and evolving way. This 2nd AVOCAAD conference also aims to be the start of the next phase in the project, which will be dissemination. Details will be announced later on.

Finally, the project would not be what it is without the continuous effort and work of Tom Provoost. A European project is a combination of very deep insights of the partners together with a lot of practical (and administrative) work. I'm sure Tom contributes to both of them.

The feedback from our scientific committee facilitated our decisions. This also influenced the scheduling of the conference.

In Brussels, we are lucky to have support from a phantastic group of people: Nele, Claudine, Jeanine, Inge, Conny and Rita, Jimmy and Lieven and everyone who has participated in the preparation and organization of the conference. Thanks for making all this possible! Finally, we have the ongoing support of the head of our Institute. We owe Lode Janssens a debt of gratitude for supporting all our activities!

Last but not least, if we look at the contributions in this book, we have to thank all contributors and already now, look forward to all discussions and the workshop during the conference. We hope you also enjoy!

Johan Verbeke
AVOCAAD

AUTHORS
Johan Verbeke
Tom Provoost
Hogeschool voor Wetenschap en Kunst
Institute for Architecture Sint-Lucas
Paleizenstraat 65, B-1030 Brussel, Belgium

Johan Verleye
Johan Verleye Architect bvba
Houtemstraat 15, B-2600 Antwerpen, Belgium

Koenraad Nys
Star Informatic
Rue du Pré Aily 24, B-4031 Angleur, Belgium

Rob van Zutphen
Henri Achten
Arthur Turksma
TUEindhoven
Faculteit Bouwkunde
Den Dolech 2, NL-5600 MB Eindhoven, The Netherlands

Gernot Pittioni
Ingenieurbüro Pittioni
Pippingerstrasse 102, D-81247 München, Germany

Alexander Asanowicz
Adam Jakimowicz
Technical University Bialystok
Faculty of Architecture
ul. Krakowska 9, PL-15875 Bialystok, Poland

Jonas af Klercker
Technical University Lund
Faculty of Architecture
Box 118, S-22100 Lund, Sweden

KEYWORDS
ABSTRACT

The Leonardo da Vinci pilot project AVOCAAD (Added Value of Computer Aided Architectural Design) aims to innovate the use of computers in architecture. Hereto, new course materials and structures are developed. Focus is on new unusual ways to use software in Architecture. In this paper, we first describe the context using the general AVOCAAD statement. In order to give structure to the developed materials, a scheme was developed. This AVOCAAD scheme is given and described. In order to innovate in the architectural curriculum as well as in design offices, exercise materials will be available through the Internet. Hereto, a web-structure for the exercises was developed.
AVOCAAD

Introduction

The Leonardo da Vinci pilot project AVOCAAD (Added Value of Computer Aided Architectural Design) aims to innovate the use of computers in architecture. Hereto, new course materials and structures are developed. Focus is on new unusual ways to use software in Architecture. The project wants to benefit from the experiences in universities as well as in architectural design offices. The course materials developed will be used in the normal education of architects as well as for post-graduate education, continuous education and training-on-the-job of architects working in an office. As this last category graduated some years ago and there is now much more experience in the ‘upstream’ use of computers, especially for them, an incentive towards stimulating more creative use of computers is necessary.

The AVOCAAD statement

The original statement of the AVOCAAD project as it was also included in the proceedings of the 1st AVOCAAD conference (J. Verbeke et al. (ed.), 1997) is as follows:

“Normally, a long and tedious design process proceeds the realisation of an architectural object. During this design process, the initial ideas and concepts of the architect crystallise out in a realisable form.

The recent new technologies, the availability of computers and software which become cheaper and more user friendly, imply that (even small and medium) design offices start using CAAD (Computer Aided Architectural Design). This has an important impact on the design process, which is currently under major change. CAAD offers a lot of new possibilities and there is an increasing number of examples showing us this new technologies support and change the design process in a positive way. Nevertheless, we see an important part of the design offices is not using these new possibilities. They are using CAAD only for producing plans. Acting in this way, these offices do not gain any added value of CAAD. Although the new technologies offer a lot of new techniques and can have a positive impact on the design process, we see a lot of architects who get confronted with these new media, react in a negative way. So, it is clear new impulses are needed in order to develop the added value of CAAD to the design process and to make this positive impact clear to the architects.

In order to realise the previous goal and to react to the rapid changes in the field, it is necessary to develop new training methods, new course contents and new training material. This material has to underline the added value of CAAD to the design process. This will augment training quality and the meaning and position of CAAD in the curriculum. It will also give maximal chances to CAAD in the future. In a second phase we see a positive impact of the designing offices and the architectural Institutes on the further development of CAAD. The new training methods, new course contents and
new training materials will make the anticipation to future developments and faster innovations possible.

This can be realised in the following way. The project will benefit from the practical training program AVOCAAD-stage. The experiences will be brought together in order to develop a new vision on the creative use of CAAD. New course material will be the concrete result. This will be the start of new training and in-service training oriented towards the added value of CAAD. As a final period we see training periods in design offices during which the new developed vision and training material will be confronted with the design practice.

By incorporating this new material in the curriculum, by integrating it in a short intensive course (as part of the continuous education as young architects who finished their studies in the near past have not yet gained this knowledge) and by making it available though the Internet (for training-on-the-job), we hope to reach a maximal effect. Because of the complexity and the fast evolution, it is clear this project can only be realised by a co-operation of different partners all over Europe: design offices, software specialists and universities. We want to bring together the variety of experiences and ideas in Europe in order to incorporate the added value of CAAD as well as possible.”

Within this context a scheme was developed which positions exercises and courses depending on their intentions and content. This scheme is described in the next section. Course materials and exercises are being developed at the same time. A sample list of exercises is given in annex 1. It will be clear to the reader, this set already covers a lot of themes in CAAD teaching. The exercise used during the AVOCAAD conference workshop is also added in annex 2 as an example. Every material is placed on a web-site which is under development and which will function in an interactive way. This is further developed in the last section.

The AVOCAAD scheme

One of the initial steps dealing with the formulation of a new CAAD-curriculum was the exploration by the AVOCAAD-team of several CAAD-courses given at their and other universities. During the analyses of the results, the team was confronted with the problem how to classify all these different courses. The basic understanding of a curriculum is that it should be a set of more or less coherent courses. So the question is what criteria to use to classify the different modules in such a way that a coherent set can be defined. During the evaluation two general observations could be made. The first observation was that a part of the courses were concentrating on technical computer issues. They address CAD fundamentals, MultiMedia techniques and computer hardware. In general these courses aim to achieve practical skills and technological insight, the ‘Computer Aided’ aspects of CAAD. The remaining other part focuses on architectural design. Here, issues like basic design concepts and design theories or methods are lectured, the ‘Architectural Design’ aspects of CAAD.
The second observation was that some courses are dealing with declarative and procedural knowledge and related tools while others look at concepts and tools that support creativity and intuition.

Both observations resulted in a scheme with two orthogonal axes, bounded by a circle as shown in figure 1. Every lecturer was asked to position his course in this scheme by placing a dot and a small description of the course.

![Figure 1: The AVOCAAD Scheme.](image)

**The AVOCAAD exercise web-site**

The main goal of the AVOCAAD Pilot Project Website is to provide a tool for architects in practice and architectural students to discover the added value of Computer Aided Architectural Design. The exercises developed formulate a specific architectural problem to the ‘user’, focused on the creative use of computers. The user has to design or create the ‘object or solution’ asked, not by following a prescribed path, but influenced by his personal ideas and background and assisted by the knowledge and experiences he extracts from the AVOCAAD knowledge base. Every ‘user’ will track his path through the exercises and the related information (both internal AVOCAAD topics and hyper-linked external documentation). The AVOCAAD exercises aim to express the added value of CAAD in a general software independent way and do not have the intention to be a basic ‘drafting’ course. Yet, the reference manuals of software could be linked to the scheme on a specific layer,
providing the user with the information when he might need it at a certain point resolving the exercise.

The exercise pages contain the description (explaining the general context), the goal, the required skills, the required software (always the kind of software, rather than a specific package), the explanation of the exercise itself and what kind of result you should reach at the end. This main page has also some links that may be useful for anyone who makes the exercise: to related topics (AVOCAAD topics as well as external hyperlinks), to exercises that have the same interest or that are somehow related and to the results of other people that made the same exercise. In addition, four indicator bars give an impression on the time load, the required computer skills, the required design skills and the difficulty level of the exercise.

After finishing the exercise, the result has to be submitted to the web-site, as well as some explanation on the basic idea of your result and the path followed to come to it, where it will be included in ‘other peoples results’. Now other ‘users’ who have finished the same exercise can provide comments on your result and you can discuss other’s results. This provides a lot of reflection on the exercise you made and the path you followed through the exercise.

Figure 2: The structure of an exercise.
In this way, the AVOCAD web-site will become a discussion forum to exchange experiences and ideas in the field of the creative use of computers in Architecture, useful both for architectural students and architects in practice.

Modules, foreground and background information

In order to use these exercises in teaching, the AVOCAD partners believed it necessary to structure the exercises (see figures 3 and 4) into modules. A module is a grouping of exercises complemented with two different types of information: foreground information (or topic) which is actively part of the module and needs to be read by all users (architect/student) of the module and background information which is (passive) information that can be consulted by the user if necessary. A module is a sequence of foreground information and exercises. It is possible to attribute to each task/exercise or to each module a deadline for submitting the result. A grouping together of different modules is called a curriculum.

Figure 3: Exercises, modules, foreground and background information.
This structure enables the teacher or individual user to use all available information and exercise materials to generate new entities: modules and curricula. These can be given to groups of students/users. As exercises and foreground information can be part of several exercises, the database forms a huge archive of materials a teacher can select to compose the task for an individual or group of students. This offers all CAAD teachers the possibilities to share experience and insight in added values offered by software to architects.

Set-up

The exercises are put into a database which also contains information concerning the user, foreground information, background information, deadlines, content of modules, user types, … Using a normal web-browser an architect or student can access the AVOCAAD-site (www.avocaad.org) and get access to the AVOCAAD server. This server (using scripts) generates the web pages the user will see on his browser (see figure 4).

This allows the AVOCAAD group to structure and maintain the database, keeping an overview of the available exercises. Moreover, adding and reorganising exercises and information becomes very easy.

Different users

As mentioned before, the AVOCAAD system will be used in the normal education of architects as well as for post-graduate education, continuous education and training-on-the-job of architects working in an office. Each user will interact with the database in a different way defined by his user-profile. For the moment the following user profiles are defined:

- Guest: general information, no interaction with course materials;
- Student: follows a predefined curriculum or module defined by his teacher;
- Professional: can select his own exercises and compose his own module;
- Teacher: selects and creates exercises, foreground and background information, modules and curricula;
- Editor: local manager, selects for local server;
- System manager: overall technical overview.
An extensive description of these user profiles can be found in R. van Zutphen et al (1999).

It is important to notice that any real user can access the database in different user profiles: a student can access as a professional, or a teacher can access the database as a student. Therefore, once a user has accessed the AVOCAAD site, he is not bound to one single user profile. People who can alter or change the content of materials (rather than uploading) have more freedom in changing user profiles than for example students.

**Functionality**

The functionality for the moment supports the following items:

- Curricula (see figure 6);
- modules;
- exercises (see figure 7);
- foreground and background information;
- pages with results;
- pages with related information;
- pages with related links.

This functionality will be extended with web pages to enter exercises, foreground and background information.
Depending on his user profile, a user has access to some of these functionalities. This way, the database can be kept accurately containing the right information.

![Curriculum Rendering](image)

**Figure 6:** To do list for a curriculum.

### Conclusions

The AVOCAAD group meets regularly. Due to intense and frequent discussions the meetings, the current web-site and exercise materials were developed. Moreover, communication between the partners is taking place by e-mail and through the announcements on web pages. Experiments with students show they work very enthusiastically on the proposed exercises. The first results show very interesting answers of the students.

The scheme and the availability of exercises on the web-site provide a powerful tool for further development of course materials. The interactive exercise web pages provide a forum for discussion and exchange of experience and ideas towards the creative use of computers in architecture.
It is the intention of the partners to develop more materials and to test them with architects in practice and with different groups of students. Moreover, action will be taken towards design offices to introduce the exercises as a way to innovate and to stimulate a different use of software for architecture.

The web-site and the web pages generated out of a database generate a powerful environment for organising and structuring exercises and course materials. It is the intention of the partners to enhance and extend the web-site in functionality as well as in number of exercises and themes covered. This way, it will offer all CAAD teachers materials they can use and the AVCOAAD system will be a tool for them to create and manage CAAD courses.

**Acknowledgement**

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The AVCOAAD web-site can be visited at: http://www.avocaad.org.
References


Appendix 1: Sample list of available exercises

Scale modelling
Image editing towards exciting couples
Space- Geometry
The sitting (computer) man
Variations in a space
Authoring the architect’s visual presentations
Interactive communication links with « buttons »
Horizontal stabilisation of multi-storey buildings
Photo sequens
Image editing to explore dynamism I
Image editing to explore dynamism II
Mirroring
Virtual scale modeling
Virtual scale modeling (second part)
Adding expressions to a model
Focused design
Decomposing a cube
The deconstruction of a cube
The building box
Musical interpretation of Architecture
Sound in space
Extracting Architecture out of Music
3D Image Composition on Cubes I
Cube Composition
3D Image Composition on Cubes II
Animation between cubes I
Animation between cubes II
The Living Model
Color Cubes I
Color Cubes II
Inverse modeling
3 in 1 – Metamorphose
Changing Design
AVOCAAD, the Story
Image Layering
Imagine and play - sketching with paper, pen, scanner and computer
Christmas Card
Stadion
Tent roof
Stairs
The gallery – Sketching with a CAAD modelling tool
Summer house
Base of roofs
Computer realistic rendering
Cosy corner – Light
Virtual scene – QuickTime VR
Facades & sections from 3D
Complete a drawing with 2D
Cost calculation
Story-board – Authoring the architect’s visual presentations
Buttons – Interactive communication links
The image archive – Archiving a project
Slide show – sequential presentation
Moving like mad – GIF animation
Concrete column
Concrete beam
Steel column
Steel beam
Steel truss girder
Steel beam, underspanned
Wooden column
Wooden beam
Wooden truss girder
Wooden beam, underspanned
Foundation, linear and punctual
Flat Foundation on concrete plates
Foundations on poles
Steel-wire construction
Aluminium constructions
Forces in wind girders (truss girders)
Stabilization by shear walls
Stabilization by frames
Stabilization of a high-rise building
Energy consumption in buildings
Basics of facility management
Building costs
Morphogenetics: first steps
Graphic information processing
From motto to composition
Light and scenography
The sitting computer man
Designing the entrance
The use of a room
Variations in a space 1
Variations in a space 2
Extending the house (garden)
Modelling and sketching (with pencil)
Inverse design
Appendix 2: Example of an exercise description

SOUNDOSCOPY

Description
Architectural spaces can evoke sound or music as well as sounds can evoke space. The perception of spaces is definitely coloured by sound or music. Endoscopy is used to represent Architecture by pictures taken inside a model. In a similar way, ‘Soundoscopy’ could be the term for representing Architecture by sounds or music.

Goal
Creating spaces and images, by analysing music and extracting atmospheres and feelings out of it. Stimulating space design by imagination and designing/modelling this spaces from scratch in a virtual computer environment.

Required skills
Architectural design skills
3D modelling
Rendering

Required Software
CAAD software, 3D modeler, Render software.

Exercise
Create an architectural sculpture in the given environment (see VRML file above and the photographs) that is a subjective reflection on the presented piece of music or on a fragment you select from it. Make 5 (rendered) images to present your design. The 5 images together give an overview of the sculpture.

Result
- A 3D model in VRML format that represents the given environment with the designed sculpture in it
- 5 images in GIF, JPG or PNG format that give a global image of the sculpture
DRAWING, SEEING, AND REASONING: THE ADDED VALUE OF COMPUTER AIDED ARCHITECTURAL DESIGN

AUTHORS
Mark D Gross
Sundance Lab for Computing in Design and Planning
University of Colorado
Boulder, Colorado 80309-0314 USA

ABSTRACT
Viewing computer aided design in the context of the history of tools and media in architectural design reminds us that tools have consequences on the way of working. Design involves seeing, reasoning, and drawing in an iterative and interactive process. These three activities provide a framework for addressing the question of ‘added value’ in architectural design. A number of recent projects at the Sundance Lab illustrate how computer aided design can support these various activities.
DRAWING, SEEING, AND REASONING: THE ADDED VALUE OF COMPUTER AIDED ARCHITECTURAL DESIGN

Design Tools and Media

As we contemplate the added value of computer aided architectural design it may be useful to consider the history of other tools and media in design. Certainly, computers and information technologies appear to be reshaping the discipline of architectural design. The practice of architectural design has changed over the centuries and a brief look at the history of design technologies and media may help us understand the significance of the changes that we are witnessing today. Architects have employed various methods to organize the design of buildings. For example, throughout the history of architecture architects have used arithmetic, geometry, and grids to control the positions and dimensions of material and space elements of buildings. Each method constrains the possible arrangements of form. Arithmetic was the main design tool for classical architecture, in which the plans and elevations of buildings depended on simple ratios (e.g., 1:1, 1:2, 1:3) of dimensions (Hersey 1976). Geometry was the predominant method in architectural design for the designers of Gothic cathedrals (Gimpel 1980). Geometric design allowed buildings to have dimensions that were not simply additive: the intersection of two arcs, for example, locates a point that cannot be fixed arithmetically. Architects have used grids to control the positions and dimensions of built elements. The Romans used the grid to lay out their military camps; and many modern architects have used systems of grids to organize their designs.

Various physical media have also been used to support designing throughout the history of architectural design. For example, tracing paper, so common in architectural offices today, is a relatively recent addition to the toolbox. Drawing tools too—the pencil and the ink pen—have evolved over the centuries (Petroski 1992); for example, the often-used felt tip colored marking pen is a late twentieth century invention. The techniques used to make drawings—projective geometry, the construction of accurate two-dimensional representations of three-dimensional space, in isometric, axonometric, and perspective projection—are also relatively recent developments. Perspective drawing, developed in the Italian Renaissance as a painter’s tool by Brunelleschi and Alberti, proved to have profound effects on architectural design and more generally on scientific thinking (Ivins 1973). Perspective representations enabled architects to construct visually accurate drawings of a building, and it has been argued that the adoption of perspective as a design tool led to changes in the buildings that were designed.

Thus, computer aided architectural design is a development in the practice of making buildings and places that we can view in the context of other historical development. Like any tool, it implies ways of working, or what was called in the 1960’s and 1970’s ‘design methods’. The impact of computers and communication technologies on architectural has been so sudden and apparently great, that it seems at first difficult to grasp the question of “added
"Drawing, Seeing, and Reasoning: the Added Value of Computer Aided Architectural Design"

Perhaps an examination of the activities in designing can offer a framework addressing this question.

The Seeing-Reasoning-Drawing Triad

It has been proposed that designing is an iterative process of seeing and acting, or as the late design researcher Donald Schön put it, a ‘see-move-see’ cycle (Schön 1992). That is, the designer articulates a proposition by making an external representation such as a drawing, studies the drawing, for example evaluating it with respect to design criteria or goals, and then makes another proposition as a result of the study or seeing. In other words, in this view three processes make up the designing: seeing, reasoning, and drawing. In computational terms, we might call these processes: input, processing, and output.

Conventional modelling and drafting software, for example, supports primarily the ‘Drawing’ process. Architects use this software to produce external representations of buildings for evaluation and presentation. Knowledge based tools such as expert systems, simulations of heating, lighting, and structural support, and building product models and object ontologies support primarily the ‘Reasoning’ process. So far, little software has been written that supports the ‘Seeing’ process, but that may well change as machine vision technologies improve.

The following sections describe projects carried out over the past few years at the Sundance Lab for Computing in Design and Planning, locating the projects with respect to Seeing, Reasoning, and Designing. Of course, some projects fit better than others into the scheme and some projects could fall into more than one category.

Seeing

Seeing imagery produced by computer has been limited in various ways by the technologies available. Early computer graphics were produced by teletype and line printer, with gradations of tone produced by overstruck characters. Drum and flatbed plotters produced line drawings in a limited number of colors, without variation in line weight or tone. Only recently, with the development of low cost inkjet printers, has acceptable hardcopy output become available. Screen imagery has likewise been limited. In the early days, CRT displays produced monochrome line drawings; raster displays have gradually increased in spatial and color resolution to where the image quality is now acceptable, though still limited in size. Immersive imaging (head mounted or CAVE displays) offers ways to go beyond the fixed screen size, although the application of these technologies in architectural design are still not mature. A remarkably effective low-cost alternative to immersive hardware has been panoramic imagery within a window, as offered for example by Quicktime VR, and similar freeware alternatives, which enable the construction of interactive 360 degree panorama pictures that can be viewed in a window. Virtual Reality Modeling Language (VRML) and its successors are a more computationally intensive, but effective way of viewing buildings and places.
Two recent projects, Ceren Virtual Archaeology project (Lewin 1997) and the Hagia Sophia Web Resource, as well as efforts described in B.J. Novitski’s book, “Rendering Real and Imagined Buildings” (Novitski 1998) illustrate the possibilities of enhancing the “seeing” process. In these projects, panoramic photographs or VRML models enable architects to explore an on-line representation of a place, real, historic, or imagined. The computer screen is a window onto a larger three-dimensional virtual world, and the visual representation of the world is linked with additional information. Jen Lewin and Mark Ehrhardt’s Ceren Virtual Archaeology site comprises a collection of multimedia information, including renderings of computer models of the excavated buildings. Ceren also offers field specimen data about the buildings and artifacts through a database that is linked to items shown in the panoramic renderings. Mark Ehrhardt’s Hagia Sophia Web Resource project (figure 1) links close-up photographs and interpretive text about the building’s construction and history with the panoramic imagery. In both these examples, the computer presents images of architecture that are enhanced with additional layers of information beyond the visual appearance of the place.

Figure 1: The Hagia Sophia Web Resource links historical information to panoramic pictures. Purely visual imagery is enhanced with overlays of integrated and linked information.

**Reasoning**

Many efforts have been made in computer science and artificial intelligence research to construct computer programs that reason. Some of these, such as the Deep Blue chess program, now perform as well or better than people, within a limited and well-defined domain. A large array of software techniques is available to researchers who are trying to automate or augment human performance in design reasoning tasks. The challenge remains for design researchers to articulate architectural design reasoning with sufficient clarity that it can be coded.
My own CoDraw program and subsequently Construction Kit Builder project both explored the idea of design as a process of making and following a system of rules (Gross 1992, Gross 1996). In both these programs, the designer specifies constraints, or rules, that govern the arrangement of design elements. The CAD program is then responsible for seeing that the design obeys these rules, as the designer adds to and modifies the design. Both CoDraw and CKB support both rules about relative positions of elements, as well as rules that govern the placement of elements with respect to a grid.

Ellen Do’s IsoVist program is an example of support for a different kind of design reasoning, the evaluation or analysis of a design with respect to performance criteria (Do and Gross 1997). IsoVist offers an analysis of the visual field of a floor plan. The designer locates a standpoint in the floorplan, and the IsoVist program calculates the area visible from that location and displays that area as a shaded region in the plan.

Figure 2: The IsoVist program calculates the viewshed from a standpoint in a floorplan; simulation programs can help designers evaluate the performance of building designs.

**Drawing**

Until recently, the production of drawings was done by hand, using pencil or pen on paper; hand-work is now augmented by computer aided drafting and modeling. Many of the drawing and drafting programs are quite limited in their expressive ability; they allow only hard-line drawing using geometric primitives; and they depend on a structured menu human-computer interface. They do not substitute for freehand exploratory drawing.

Our ‘Back of an Envelope / Electronic Cocktail Napkin’ project is based on the observation that designers draw diagrams to explore concepts during early design (Gross 1996). Therefore, the computer should be able to recognize and interpret designers’ drawings. Once the computer can participate in the graphic dialogue, it may be able to offer advice, simulation, or other activities that support design reasoning. At the core of the project is a recognizer for symbols drawn freehand and a parser for configurations made up of these
symbols. Other layers of the project are built around that core. We’ve built “sketchy” interfaces to visual databases, simulation programs, and other applications. For example, we’ve built a sketch interface to the IsoVist program described above, and a scheme for indexing URLs in the Web using diagrams. Ellen Do’s “Right Tool at the Right Time” manager attempts to guess what the designer is doing by watching the drawing, and based on its guess, it offers what may be an appropriate knowledge tool. For example, if the designer is drawing sun rays, it offers a case library of daylighting solutions (Do 1998).

Design is team work, and often several designers, engineers, and other concerned parties work together reviewing and making annotations on a drawing. In architectural teaching, too, the desk critique is a common way that teachers interact with students, drawing on the student’s design work to make suggestions. Dongqiu Qian’s NetDraw is a Java based collaborative drawing program that supports collaborative drawing over the Internet. It enables several designers to share a drawing workspace, drawing on top of an overlay and making graphical gestures to point out what they are talking about in a linked text chat application. It goes beyond conventional whiteboard and conferencing applications by providing support for synchronization and concurrency control, grouping and simple graphical constraints on drawing objects, and ephemeral ‘gesturing’ that disappears within 30 seconds after it is made. NetDraw also communicates with AutoCAD and our Back of the Envelope program. We’ve designed it to run on mobile platforms, such as palmtops and Personal Digital Assistants.
Finally, Thomas Jung’s Immersive Redlining project (figure 5) is designed, like NetDraw, to support collaborative design among several designers, or to support critiquing and comment among a design team, including participation in the design process by clients. Our Redliner tool allows several participants to browse a stored VRML model and leave colored annotation markers in the model, linked to text comments. Viewers who browse the design model later can see these annotations. The designer can also prepare alternatives to certain parts of the design, allowing the viewer to modify the position, color, or material of a building element using a simple palette of controls.

Discussion
The three-part framework, seeing, reasoning, and drawing, helps organize the methods and tools of computer aided architectural design. To be sure, it is not immediately obvious where to place in this simple framework other important design activities such as communicating with colleagues, or looking up standard dimensions, or creative imagination. These questions are arguable.
Nevertheless, the framework offers a way to consider where in the process of design various computer aided architectural design tools add value.

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References
TOWARDS THE POST DIGITAL ERA

AUTHORS
John Frazer
School of Design
The Hong Kong Polytechnic University

ABSTRACT
The digital era has added little value so far to the quality of design. What were the problems? What hope is there for the post digital era?
TOWARDS THE POST DIGITAL ERA

**Added value**
To add value in computer aided design means at the very least doing something more effectively, obvious examples include improving the quality of design, improving the design process, providing better analysis of building performance, better modelling of appearance, allowing more accurate building information, providing opportunities for public or user involvement in the design process, opening up new vocabularies of forms or building process or technologies, being able to design quicker, encouraging more environmentally responsible architecture or just making more profit for the designer. Over the last thirty years a variety of CAD techniques have been developed that have addressed these and other issues but usually in a fragmented and partial manner. Much of the promise of proprietary systems has not been realised and many academic dreams unfulfilled. I think it is time to take stock of what has been achieved and to try to describe the characteristics that we might desire of future systems and identify new avenues of research.

**Active and passive tools**
It is useful to differentiate between passive and active design tools. There was a time when those, often wishing to be dismissive of the potential of computer aided design or feeling threatened by it, talked of computers being “just a tool”. They were almost certainly talking of passive design tools, and indeed may not have been aware of other kinds. Active tools, had they known of them, might have scared them into taking an altogether more aggressive stance. Passive tools were not a threat to their outdated work methods and could be safely relegated to a technician.

But however useful passive tools such as drafting systems and modellers may be they add relatively little to the design process itself. They may indeed take away from it. On the other hand active tools such as generative systems have the potential to add great value to the design process itself.

**Was the problem ever clearly defined?**
I do not think that it is essential to have a clearly defined problem to get a good solution. In fact architectural and design problems tend to be categorised as ill-defined as part of their charm. But in the case of CAD it was not clear what the problem was at all. Can anyone remember what it was about designing that needed aiding before computer aided design came along to provide this aid? Aid that was not needed, in the minds of many practitioners who were more or less driven by market forces into the use of computers they didn’t want, could not afford nor could see what they had to offer. No wonder we have now inherited a very confused position.

Those who took a different view were either those who regarded the existing design process as fundamentally flawed and ineffective or those who had an agenda which implied a radically different approach. In my case I embraced both these imperatives for the use of the computer.
I had a problem which has been stretching available computer power for thirty years. But I think I was lucky to have such a problem that needed an aid. For me the computer was never just a tool but was an indispensable enabling device that continually inspired me to push my demands further.

So computers were the answer, but what was the problem?
A thought experiment: At the Architectural Association in London in the late 80s to mid 90s I ran a series of exercises called "computing without computers". You had to forget limitations of memory and speed, idiotic programs and clumsy and inappropriate interfaces. Instead you imagined you had unlimited computer power, intelligent software that would do anything that you desired and any form of input and output devices that you could dream up. The question was “As a designer, what are you going to use this for?” As we move into the post digital era we will have such devices and the whole emphasis will be on integrating them into our society, our lives, our ecology, our future, and our creative activities.

[The Conference presentation of this paper will be illustrated at this point by a series of examples of work originating from these thought experiments]

A world in bits?
The end of the 20th C is characterised by everything falling to bits! This is manifest by a general tendency to reductionism and by an obsession with digital technology. The trend is epitomised by “City of Bits” and “Being Digital”. Perhaps these outbursts by Mitchell and Negroponte represent the end of that line of thought. Reducing the dynamic range of music to 16 bits may solve some quality problems but it has bred a generation that has not heard the dynamic range of analogue sound. The gradual introduction of 20 and 24 bit systems is a partial (or bitty) way of producing a simulation of analogue sound. So too gradually the dreaded screen jaggies of curves and diagonals are being successively approximated with more and more pixels until a visual deception of smoothness is produced - a very crude solution. At the turn of the century we can still only read part of a page on our word processor (this was also a problem with early hammer action typewriters at the end of the 19th C). Quartz clocked computerised watches have gone through that dreadful stage when people told you the time was 14.37! Mainly the quartz/computer technology is used to drive stepper motors to display the more rapidly assimilated and relativistic system of the traditional clock face. The watch industry has thus simultaneously demonstrated its innate conservatism but also being largely gnome rather than nerd driven they have resisted technological purism and been able to combine the best of both worlds.

There is a lesson here for architecture as we move into the post digital era!

The convergence of the virtual and the actual.
I believe that we are experiencing a convergence of the virtual and the actual.
Remember the binary system of on/off, 0 or 1, true or false, was only introduced because transistor technology at the beginning of the computer era was unable to cope with subtle differentiations of voltage. So instead of developing better transistor technology large number of crude devices were thrown together to form families of logic gates which then underpinned a whole generation of machine code level languages. This thinking has infected the fundamental structure of computer languages ever since. Worse still the infection has spread too much related thinking in areas such as CAD.

New analogue techniques, new chemical and biological forms of computers will soon free us from the tyrannies of the digital world that dominated the end of this century. Different forms of logic will be possible and we can break from the Cartesian display format of the screen and use relative rather than absolute systems. Subtle chemical gradations of meaning and colour will replace binary thinking and pixellated displays. But can the nerds change their thinking to match the new possibilities? May be not. Maybe the train-spotters with their obsessions with chip numbers, clock rates, gigabytes of dates and megabits of bandwidth will go along with their puerile technobabble. But who will be the new appropriators of this technology? I believe it will come from those who have real problems to solve in the real world and can see the solution in a marriage of the virtual and the actual.

The alternative scenario is horrific. Wide scale information pollution. Information everywhere but with all intelligence and meaning lost. “Data, data everywhere but not a thought to think!” (Apologies to the originator of this quote – I have lost the reference) An endless field of white noise of information. Do those talking of an “information economy” really know what they are talking about?

And the post digital era?
I view the future scenario as mainly positive – but with some warnings.
MEDIATION

AUTHORS

Ben Van Berkel
UN STUDIO
Stadshouderkade 113
1073 AX Amsterdam
The Netherlands
info@unstudio.com
New media have been successfully taken up in music, films, car design, fashion, magazine and book publishing, the sex industry, and education. Only architecture and urban design are slow to incorporate new media technologies. To some extent, architecture and mediation are locked into a conflicting, for the most part mutually excluding, relationship. At first sight this looks logical; architecture is a place, a real, once-only place, which you experience by visiting it. You do not experience architecture through dissolving a building and electronically replicating it a billion times in the air. But all technology is social before it becomes a technique; the technology of mediation needs to be more deeply incorporated within the practice of architecture, and to be more widely understood and supported before it can be fully exploited as a tool. This process is just beginning; as yet there is no fully evolved ideological scope which incorporates the new mediated position as an essential part of architecture. New mediation technologies have taken over some of the functions of buildings, such as security, surveillance, and communication with the outside, but these are not the most relevant aspects for the practice of architecture itself.

The three most important architectural potentials of the new mediation techniques are: the expansion of the spatial imagination, the radical break with a hierarchical design approach, and the introduction of different disciplines into the design process, relating the design immediately to its final execution. To begin with the first: the tantalizing new spatial modes suggested on every computer screen result in a general familiarity with the potential of a multi-dimensional spatial experience. Computer-generated special effects express a delight in explorative spatial situations, leading to a rapid increase in the capacity for spatial conceptualization. The artificial world of the computer rendering, with its flat light shaving as sharp as a razor over planes so smooth that not a single molecule is out of line, is appalling and exciting at the same time. Gradually, we are beginning to see that this new computer-generated fantasy is being transformed into reality. The rendering becomes real; the artificiality of the image is actively reproduced in the constructed realm.

The digitalization of architectural practice takes various forms. The choice of computer software is an important factor in the procedure of the technique as different applications contain their own rules and instrumentalizing qualities. All mediation techniques have in common that they abandon the hierarchical way of building up the architectural body, which starts with the ground plan. Not the object itself, but the sets of relationships between the component parts are articulated and defined.

At the moment, there are four dominant approaches to computational and mediation techniques: the first sees the new techniques as a way to realize a virtual reality, which is related to the radical physiological interventions, disenfranchising social, political and economic powers, and inanimate environment of cyberspace. This thinking relates to a tradition of visionary architecture. Fantasies of imaginary cities and buildings are connected to cybernetics, the science of communication and automatic control systems. As with all fantasies, it is to a large extent the current reality that directs these
visions. The mediated world implies that the communicative powers of architecture have been massively overshadowed by new media. Accelerators such as motorways and airports have destabilized the public domain in which the architectural body is embedded. In this world of potentially limitless freedom of movement through geographical, social, economic and cultural strata, the old dream of transcending materiality begins to approach realization. A substantial virtual control of human bodies, and urban and architectural spaces already exists.

For now, architecture cannot be fully virtual and at the same time be a real, solid place which can be physically entered. It is only possible to extend and enrich architecture with virtual means. This entails a specific use of mediation techniques, to some extent overlapping with the process of hybridization. The most important consequence of this interpretation of computer architecture is that it explores the inventive and utopian potential of the new media techniques and expands boundaries.

A second application of the introduction of computational techniques centres on the intensification of the connectivity between the partners in the architectural process. The line between design phase and construction has shortened and has unravelled into different, non-simultaneous strands. The traditional order of the design stages has broken down, with reality checks on money and feasibility being worked into the process at the earliest moment. Traditionally, the period of preliminary design would be a quiet, concentrated stage, during which architects would happily prepare their designs in relative isolation. After this, a trying series of cutbacks would proceed to frustrate everyone and kill the project. Now, the architectural process may be organized in many different ways, with the widely used new methods such as 'design & construct', and 'definitive design plus'.

Designing with computational techniques involves abandoning the traditional hierarchy of a design approach which begins with the plan. Today, we begin with a point. A point in three-dimensional space. The architectural drawing, a scaled-down, two-dimensional representation of an aspect of a building, is obsolete. A project is built up in three dimensions and with its real measurements in the infinite mediation space. Having captured this space within a personal computer station, that is, having confined it to proportions which enable us to manipulate, divide and layer this space, it goes ahead to generate its own small technologies like extrusions, and rotating sections, little tricks which simply let us see more than before.

While the software programmes compatible for engineers and contractors have not been written for architects and are far from user-friendly, the up-side of connectivity is that more can be achieved. Complex projects, assembled from components of many different shapes and sizes, are realized thanks to computational techniques. Constructions that deviate from the mainstream are becoming accessible to architects, because along with everything else, the knowledge that belonged exclusively to engineers is also being injected into the design process at an earlier stage. Digital calculating enables more complex geometrical structuring. Meanwhile, production methods have also changed under the influence of the development of new mediation technologies. Computerized laser-cutting mills execute complex shapes with
the same ease as rectangular ones, so that non-standardized profiles and details become cheaper.

This, in combination with the changing, and in some ways diminishing, role of the architect informs the third approach to computer architecture. This third adaptation revolves around the objective, pragmatic properties of techniques. The techniques offer an opportunity to hang on to a belief in reason, in there being a right choice to make. Otherwise, it has become difficult to rationalize design choices. If any form is possible, and all are equally functional in an economic sense, the pragmatic, standardized language of Modernism has lost its imperative. A simple, self-evident reasoning no longer justifies any specific form. With the criteria for functionalism changing, and the co-operative design process rendering uncertain the position of the architect, new digital techniques are exploited to shake off traditional architectural pretensions. The third adaptation of new techniques implies that new models of organization are developed in order to proportion and structure digital information. Parameters are formulated, once again expressing architectural values in rational, functional, and objective terms. As the evolution of the chosen parameters is traced over time, the project emerges as if of its own accord. The techniques are used as a direct and transparent medium to uncover the neutral values forming the basis of the project. This approach has some similarities to the rationalist and structuralist architecture of the 1960s. Both share a conviction that a neutral, business-like architecture can emanate directly out of underlying data, uncontaminated by the personality of the architect or by aesthetic conventions.

While this approach already begins to incorporate moveable criteria, parameter design is primarily a static summing up. Only when the data begin to interact, do the elements of time and movement enter the process. At that point, the fourth important adaptation of new media techniques enter the equation: animation. This approach entails a different choice of software, focusing on time-based animation software environments such as Silicon Graphics, which are no more designed for architects than CAD systems, but which take the design process in a new direction. Three-dimensional modelling already dispenses with the idea of the designed object as the construction of outlines and instead begins with a point; animation abandons even the network of points, and focuses on the interrelations of parameters and forces. The object is formed as the result of this process; it is the solidification of energies acting on each other, as in a chemical experiment. The animation technique involves setting up a path. The end result is subject to change as long as the project follows its course.

In a controlled experiment the choice of ingredients is vital to the outcome. Therefore, it would be an exaggeration to see the project as the passive product of a self-organizing process, but this technique still involves greater openness with reference to the end product than any other technique. The fact that objects are modelled by means of a dynamic process implies that changes in the organizational patterns taking place during the process are also evaluated, enabling a complete acknowledgement of complexity.

Animation as a technique could not have been developed without virtual architecture and parameter-based strategies; in a way, animation hybridizes
the two and optimizes certain potentials. There is a tendency for architects, probably because of the large investments of time and money required to become digital, to focus almost exclusively on one specific usage and heavily integrate it into their design approach. This total identification of practices with specific techniques is now the factor which most inhibits the successful integration of mediation technology in architecture. Let's put an end to digital sectarianism. The potentials of mediation, the expansion of the imagination, the break with a hierarchical design approach, and the introduction of different disciplines into the design process, go beyond the small technologies. Architecture needs the varied and free use of new mediation techniques in order to keep its relevance as a public science with tentacles in areas such as design, art, film, computer technology, engineering, and infrastructure.
A COLLECTIVELY DESIGNED INFORMATION LANDSCAPE

AUTHORS
Maia Engeli
Malgorzata Miskiewicz-Bugajski
Architecture & CAAD
ETH Hönggerberg
Zürich, Switzerland
[engeli,bugajski]@arch.ethz.ch

ABSTRACT
"Information Landscape" is one of several courses in which we explore the potential of networked environments to support creative, collaborative design processes. 180 architecture students of the first semester are participating in this course. They work in pairs. The design of an "Information Landscape" is the goal, it is a virtual terrain that is formed by the participants over time and has landmarks that lead to specific information. The location and visual appearance of the more than 400 landmarks help to remember which information is connected to them. The design of the landscape happens in five steps and is related to the tasks in the architectural design class. The collectively designed product can reach qualities beyond the possible achievements of a single person. An environment that supports such design goals must provide for motivation, transparency and support. The common product has to include a tolerance towards fluctuations in the quality of the contributions.
A COLLECTIVELY DESIGNED INFORMATION LANDSCAPE

1. Introduction – Focus and Preconditions

In this paper, we are presenting the course "Information Landscape", an introduction to information technology for architecture students. The two aspects we are going to focus on are the learning environment, including its social aspects, and the collectively designed product that resulted from this course. The goal of the course exercises was to collectively design an "Information Landscape". A digital two-dimensional terrain was formed by the participants over time and enriched with landmarks that lead to specific information. The location and visual appearance of more than 400 landmarks help to remember which information is connected to them, hence the name "Information Landscape".

"Information Landscape" is one of several courses in which we explore the potential of networked environments to support creative collaborative processes for learning and the design of a common product. This approach to learning leads to new and most appropriate uses of the World Wide Web (WWW), which was originally invented as a distributed information retrieval system to support the exchange of information among scientists at the CERN High-Energy Physics laboratories (Berners-Lee, 1989). Even though many educators agree that the use of the Internet for teaching has to go beyond the documentation of learning material in digital form, videotaped lectures and multiple choice tests, the development of more sophisticated environments is still in its infancy. It has been recognised that learning is a creative process and does not happen in isolation from discussions with other learners and teachers. "Exploration and learning can be used as synonyms, they are a process of knowledge construction within a social context" (Bers, 1998). With respect to learning environments, it has been pointed out that "Education happens in social institutions not virtual ones" (Keil-Slavik, Selke, 1998).

Two preconditions are important to be mentioned. First, this is a mandatory course. About 180 students had to take it and complete the exercises. A survey at the beginning of the semester showed that only half of them were looking forward to working on the computer. Second, the course is taught over six weeks at two hours a week, one hour for the lecture and one hour for the work on the exercises. This is very little time, but on the other hand, it also becomes an interesting restriction as it leads to thinking about efficiency in the learning and design process. An important measure was to group the students in pairs for the exercise work. The landscape was divided into 96 rectangular patches of 300 by 400 pixels each, with every group working on a single patch. This is a first semester course. The main theme of the course focused on special aspects of information technology. Architectural design is taught in a different course. Our intention was to avoid interference with what they learn there, yet still to use the same theme and show how it can be applied in a different context, so that the students can broaden their sense of what architecture is all about.
2. Goals in Creative Collaboration, Architecture and Learning

2.1 Creative Work in a Networked Environment
To offer a networked environment, for creative collaboration is of great importance for the course. By representing the simulations of the future working environment, students can explore the positive and negative sides of the system while developing and experiencing new strategies to achieve successful results. The positive sides are related to the goals that can only be achieved as a coordinated group work, whereby one has an open access to the resources assembled in the system by other users. The negative sides are mostly connected to the fact that parts of the system are given and cannot be modified by the users. The individual contributions depend on the opportunities given by the system as well as the visibility of the particular work. The profession of the architect depends on many systems: political, economical, social, technical, and procedural. To learn to carry through own ideas within restrictive fields of influence is an important precondition for becoming a successful architect.

Communication, collaboration, and responsibility are the central issues that students have to deal with in a networked learning environment we are offering. Communication is required to explain one’s own ideas to other individuals and/or the whole community. Communication becomes a must especially when obtaining additional information from another source is necessary to complete required task. Collaboration, in its simplest form, happens through the summation of the individual contributions. More complex forms of collaboration require an exchange of information in order to understand the work done by others as well as to understand the working process in which many individuals can take part. Finally, responsibility is crucial to realize that the work of every individual becomes a part of the system, and that good contributions augment the overall quality, while bad ones have a diminishing effect.

Being part of a system means also to see how one’s work can influence the others and which works are influenced and shaped by other creative streams. It teaches to become strong and clear in presenting the ideas and helps to see the effects of different presentation strategies. It allows to observe decisions made by others and to learn about the results of those decisions, so that one can evaluate them and further incorporate as one’s own sets of strategies.

Our goal was to provoke the investigation on the qualities of multidimensional information spaces, which can be evoked by collaborative design within the networked system. Students learned about new ways of interpreting and representing the spatial relationships within a two-dimensional image while learning how to organize the collected information.

2.2 Architecture and Information Architecture
The investigations described above lead to the introduction of the notion of an Information Architecture (Wurman, 1996) based on the concepts of system, communication and information. As architects, we deal with the problems of organizing the information about a project. By creative “putting together” of the facts and needs, we are able to propose a solution and present an idea for a new form of spatial organization. By bringing the data to the system, students are confronted with the need for new way of formulating the message by means of inventing visual languages, which are then used to present the idea in the form of digital image. As part of the course, students were confronted
with aspects of structuring the information in the way so that the idea can be shared with others. The discourses about the physical spatial relationships and its two-dimensional pixilated representation on the computer screen resulted in developing many interesting strategies, which were subsequently used as methods for organizing the collected information onto 96 patches of the information landscape.

2.3 Learning the Facts and Learning through Experience
Experience of working in a computer mediated networked setting has important long term effects and is given preference over teaching of facts and giving instructions. In the realm of computers and networks, development happens so fast that one’s personal know–how has to be constantly renewed. How does one decide what to learn? How does one decide how to achieve a task? No longer will fixed recipes be at hand. One has to stay flexible and open–minded. The exploration of possibilities is necessary to reach optimized solutions. Experience is needed to judge and integrate anything new that one is confronted with. Experience is the basis for the achievement of future tasks.

3. Environment, Themes and Tasks

3.1 An Internet-based Environment
The digital environment of the course was built as an Internet environment. It is globally accessible with a standard Internet-browser at http://alterego.arch.ethz.ch/. A fast connection to the Internet is advisable for accessing the landscape, otherwise downloading of the images may become cumbersome. The monitor resolution should be 1280x1024; with a smaller resolution, some scrolling will be necessary. With these prerequisites fulfilled, the students can do part of their work from home and show it to friends and family outside the school.

Through the interface of the course, numerous bits of information are accessible, such as: lectures, exercises, tutorials, technical help, teachers and their email addresses, a sign up system for coaching, landscape and the read–write level. In addition, teachers have a note system to keep track of the progress and intentions of each student group. The design and structuring of the interface had to be done so as to enable a fast and obvious access to each bit of information. Three main interfaces can be distinguished: the INFO interface, the MAP interface, and the READ-WRITE interface.

The INFO interface is also the entry interface into the course. The menu on the left gives access to many relevant documents, whereas the one on the bottom serves as a link to the MAP interface.
Figure 1: The Entry page of the course and at the same time the INFO interface.

The MAP interface shows only a part of the landscape, three times three patches out of 96. Possibilities to navigate through the whole landscape, as well as in time, are provided.

Figure 2: The MAP Interface and the relation of the view to the whole landscape.

From the MAP interface, the READ-WRITE interface can be accessed. It allows to "talk" to one’s neighbors and other participating groups. The online messages that were passed, and the discussions that went on, are displayed on the right side of this interface.
The underlying system uses a database to collect information on many levels. Most important are the services that it provides to the users. First, the sign-up process must be automated. Since the students worked in pairs, every group had to be registered and a patch out of the landscape had to be assigned to them. Whenever a group logged in, the system would automatically show their patch in the center of the MAP interface and go to their communication in the READ-WRITE interface. Since the landscape is very big (15.5 Megabytes in GIF-Format), the part to be displayed over the Internet is always composed on the fly.

3.2 Themes of the Lectures

Information technology is a very broad field. There are an infinite number of themes for the lectures. Our course is too short to cover the whole field, therefore we have chosen to exemplify methods for understanding this new and fast developing field rather than trying to teach basic facts. The first lecture was devoted to the introduction of the course. In the last week, all the time of the course was used for reviews of the individual contributions. The themes of the remaining four lectures were 1) System, 2) Communication, 3) Information Sources, and 4) Information Architecture.

In the first lecture, the notion of “System” was illustrated with examples from nature, technology, and architecture. Different characteristics of systems were identified. Then, the fact that working on the “Information Landscape” meant to
work in a system was pointed out. The advantages and disadvantages of the working environment were discussed. Similarities to the work situation of practicing architects were also pointed out.

“Communication” was the theme of the second lecture. Aspects of digital communication were introduced and many examples of current digital communication possibilities were demonstrated. The main point was to ask critical questions about these possibilities and at the same time think about innovative uses for them.

Then “Information Sources” were introduced. We are flooded with information, but where does the information actually come from? In addition to lexicons, newspapers and search engines the students named manifold other information sources. Different strategies for searching relevant information on the Internet were emphasized, because the students have to learn how to deal efficiently with the large amount of information that is accessible.

“Information Architecture “ reflected on the abstract notion of architecture and how it can be applied to make information better accessible for humans. Richard Wurmann has introduced the notion “Information Architecture” and has given a nice definition in his book “Information Architects” (Wurmann, 1996), pointing out design tactics like “organize the pattern inherent in data,” “create of paths to knowledge” or “make the complex clear.”

3.3 Tasks of the Exercises
The sequence of the exercises resulted in the design of the information landscape, the process was divided into five phases entitled: 1) Private Yard, 2) Visual Communication, 3) Verbal Communication, 4) Information Search, and 5) Information Landscape.

![Image of the sequence of the exercises](image_url)

Figure 5: Illustration of the sequence of the exercises.

In the “Private Yard” exercise, students could only see their own piece of the landscape. They were asked to do the same exercise as in the design class, namely to design a “Day Dream Space”. In the design class, they had already identified five attributes for this space. In our course, these attributes had to be placed as text on the given background, a sewing pattern. Instead of thinking about space as having three dimensions, the task was to create depth in the
two-dimensional image by thinking about visual strategies and enhancing the meaning of the attributes graphically.
For the “Visual Communication” exercise, the neighbours became visible in the interface. The borders should be regarded as locations of exchange. At these seams information can flow in and out of the well-defined rectangular patches. The goal was to be a good player in the system and possibly a good source of graphical ideas, which would be carried on by the neighbors to the next border. There, the next group would hopefully continue the theme that was initialized.
For the exercise on “Verbal Communication”, the READ-WRITE interface was enabled. Now it was possible to explain ideas verbally, to pose questions, and to ask the neighbours for specific actions on their fields. The challenge was to write short, precise and nice messages. The students had to learn to use a verbal language to describe visual qualities and intentions. After this exercise, the visual basis of the landscape was mostly established.
The next task, “Information Search”, was to leave the nice, protected, enclosed learning environment and to go out into the WWW to look for information. The task was to find five appealing Internet pages that provided interesting and correct information for the following topics: architecture, art, and philosophy.
The last exercise, “Information Landscape”, lead to the completion of the common design task. The links should be localized on the landscape by identifying or designing appropriate landmarks. This step also asked for coordination with the neighbors, so that the landscape would become a readable and mnemonic basis for the access to a wealth of more than 450 interesting links.

4. Analysis of the Landscape and the Formation Process

4.1 Visual Results
After six weeks of collaborative work an information landscape was created. It was created by incorporating the ideas of 180 students belonging to the same territory, and working collectively on its parts. Travelling through the whole landscape reveals several types of activities that occurred throughout the course. Through other students’ visual and verbal influence, many groups were able to improve and strengthen their initial contributions.

Figure 6 and 7: Visual bridges over the discontinuity of the background pattern (6). This community used billboard-like elements as a design concept (7).
Different communities emerged during the design process. The forming of the communities in the landscape materialized through visual and verbal communication. The visual communication was used in signaling for the first time the intention of belonging to a community. After the group had been accepted, the verbal communication was used to discuss the details of the “membership” and to share the knowledge about the technical ways to complete it. The communities can be identified by the unique visual language of expression they have developed.

Many actions, which lead to form a community, were indicated: 1) Following an idea of another group and giving up a personal one in order to join a common strategy and gain a stronger visual output, along with a wider recognition in the landscape. A strong wish to become a dominant landmark on a landscape helps to incorporate groups, for example by convincing them not only to accept the same color palette, but also to adapt to other parts of the design.

![Figure 8: The broadest community (“Yellow Ribbon”) represents various styles united by the same color and complementary pieces of design.](image)

For one of the communities, the background pattern became a model for the specific grayscale appearance. There were also actions, which should have lead to establishing a new dominant part in the landscape, but failed to do so. Instead, designs were created, which subsequently became isolated marks as the group decided not to redesign them.

The information landscape can be mapped onto the shape of a ring, through which one can travel continuously. The background pattern has visible seams that marked certain discontinuity in the territory. Such a junction was treated immediately as an orientation mark. The idea of bridges arose and was incorporated by groups working on opposite sides of a vertical seam. The horizontal seam was instead treated as a border which none of the groups wanted to bridge.
4.2 The Links to External Information

At the end of the course information landscape became a rich hypermap. The links added a new dimension to the landscape. It is worth noticing the ways the information is linked to the image and how carefully students were choosing and designing the graphical elements which became a link to the new information: Sometimes, the graphics are related to the subject of the link. Other times, they are related to the role the linked information plays for the design. By travelling through such multidimensional information landscape, one can experience the different interesting paths to knowledge. Several groups created communities of interest to mark the landscape with areas dedicated to specially chosen architectural or art themes. An exemplary plan was developed for the dominant “Yellow Ribbon” in the landscape. It should link to pages, which taken as a whole, document 5000 years of architectural history.

5. Conclusions

5.1 Aesthetic Quality

In this paper, we described the second launch of the course. Description and images of the first version can be found in the book “Information Architecture” (Schmitt, 1998). A major difference was that in the first version of the course we did not use words as graphical entities. Instead, we just asked students to create a graphical interpretation of their attributes. In the second version of the course, the use of typed words, and hence typographed letters that were carefully designed by a professional, enhanced the visual quality of the landscape. Nonetheless, we still faced the problem that the landscape was often criticized because of its visual output, when we print it out as a large poster. The printout then misses the level of the linked information and seems void of any message. In the future, we have to find a way to overlay this additional dimension onto the image. In its current form, the poster also does not show the design process or the communication level, the two aspects that were very important for the learning experience.

5.2 Characteristics in the Use of Language

The verbal part of the task has many important aspects, mainly that it allows for social interaction within the landscape. This has shown to have a motivating effect. Many groups used the possibility to write messages not only
to talk about strategies for the development of the landscape, but also to talk about problems and to advise each other regarding the image processing. The use of this possibility for social interaction really peaked in one dialog that almost ended as a love story. It seems that these students felt very comfortable using this possibility of the interface.

Another interesting observation is that in these very short messages the whole palette of attitudes can be found, ranging from super-nice to flaming. The use of super-nice, highly formal language is close to role-playing, an attitude that may be taken to hide shyness or insecurity. Flaming, on the other hand, seemed to originate from cultural differences. Some addressees interpreted the impulsiveness of other students from the French part of Switzerland as harsh, unfriendly critic, which lead to angry and senseless discussions.

5.3 Learning
The learning process included many aspects. The lectures should give input about the topics to think about. Then the discussion among the pairs, with the assistants and other colleagues, were important to further discover the complexity of the issues and come to some conclusions. Social competence, life-long learning, and education of leaders are goals, beyond the professional competence, that we want to reach in our students. These aspects can only be learned with an appropriate challenge and an environment that requires social interaction.

Working in pairs lead to more intense reflections on the task and its fulfillment. It also reduced the risk of losing time because of technical problems or lack of ideas. Motivation was also important. Motivated students are more receptive for input, spend more time on a task, deliver better results and hence learn more because they are more engaged. The motivation was enhanced by the possibilities for interaction with others within the environment, as well as by the guidance obtained from the teaching assistants.

We are certain that the students learned more than they have consciously noticed. Much is learned by seeing the work of others, from the reaction of other people to one’s own work, and by being a part of collaborative effort, where unforeseen contributions suddenly reveal new possibilities. We claim that the students have unconsciously gained experience - this enhances the efficiency of our teaching approach, because there is only a limited amount of learning that can happen consciously.

5.4 Next steps
In the next launch of the course, we may further try to enhance the aesthetic quality, however, we have not developed a strategy yet. We are also interested in learning more about the social and psychological aspects for the next course and other projects on creative collaboration.

6. Thanks
Special thanks go to André Müller, who was responsible for the course environment (built upon the work done by Andreas Weder in the previous year). The students have created the landscape with great support from the teaching team - we want to thank them for their valuable contributions. Part of the work is supported by a research grant from the Swiss Federal Institute (ETH).
7. References


AN ENVIRONMENT FOR COLLABORATIVE THREE-DIMENSIONAL MODELLING OVER THE INTERNET

AUTHORS
Kai Strehlke
Architecture & CAAD
ETH Hönggerberg
Zürich, Switzerland
strehlke@arch.ethz.ch

ABSTRACT
This work results from a postgraduate thesis done at the chair for Architecture and CAAD at the ETH in Zürich. It presents a three-dimensional modeller written in VRML (Virtual Reality Modelling Language) which allows collaboration over the Internet. The aim was to create a modeller with a set of very simple tools to create complex forms. It was intended to realise the program in a way, that the user is always able to understand and control the process of form generation. A second goal was to connect the process of form generation to the output of a database. It was intended to interact between a locally created object and objects from the database created by other students.
AN ENVIRONMENT FOR COLLABORATIVE THREE-DIMENSIONAL MODELLING OVER THE INTERNET

Figure 1.

1. Introduction
Computers have become commonplace in architectural practice. Highly complex CAD packages have been developed to help the working process in offices. Most CAD packages claim to support the entire work process from the first concepts until the cost calculation of a project. However, the applicability of existing commercial software in the early stages of a design process can be doubted, because most programs are far too complex to allow an intuitive way of designing. As a result, even today a design often is done in a traditional way and only afterwards it is translated into a digital form.

As in architectural offices, computers also have found their place in universities, for teaching architecture. In the educational environment the work process differs very much from the daily work in an office. Whereas in an architectural office, the design process accounts for only a small percentage of the overall office work, in architectural education the design process receives the main focus.

CAD packages are optimised for the production of plans and models of a completed design, not for the first design steps. Therefore, this software is not best suited for the use in education.

2. Traditional Design Education
In the Department of Architecture of the Swiss Federal Institute of Technology (ETH) students design classes are held in designated studio spaces. The essential advantage of this situation is that students can communicate during the entire design process. It allows them to discuss the different projects, thereby enabling them to learn to find the strong and weak points of their design. They receive a lot of input from the others students and they can control their own design process. When someone is stuck in his or her design process the social support qualities of the studio come into play.

A second important advantage is that students work with many different tools. Sketches are done with pencils, charcoal, watercolour, etc. Different materials are used for modelling, like cardboard, clay, wood or plastic. For each design intention an appropriate media can be choosen to express the idea in a simple but effective way.
2.1 The Use of CAD Software in Design Education

Designing with computers differs substantially from a traditional design process; especially if the design process takes place in an educational setting. The use of complex CAD packages in design education brings crucial changes. Most often students are working in front of a PC or a workstation.

Firstly, the work process is hidden from the others students. The possibilities of communicating the design steps are no longer available, because the whole work is very often located in one or more files. Only the final result can be seen, when perspectives are rendered and plans are printed out. Secondly, people use complex CAD tools for their design. The use of these tools requires a lot of time to learn the features of the package. Very often the students are not guided by their imagination and creativity but their design is restricted by how well they master the tool.

There is a need of adequate software in design education. It is important to point out the differences in processes going on in offices and in an educational environment in order to know which features have to be provided by the software for each of these. For educational purposes the tools should enable collaboration and communication between students who are working on the same project. The software should be so simple to use, that the possibility exists of an intuitive way of working with it.

3. A Prototype for Three-Dimensional Modelling Over the Internet

Given these concepts, the intention was to program a prototype which stimulates interaction between different users and provides the possibility to create complex forms with a set of very simple tools. The goal was to build a three-dimensional environment for modelling on the Internet and to connect this program to a database. It was intended to write a program which runs everywhere. The form generation process should be comprehensible and thus controllable. No filters should be applied, which would enable spectacular forms, but would complicate an understanding. In a first application step, a set of simple tools are provided to build a model. This modelling process is done locally without any connection to the database. In a second step, it is possible to submit the model to the database or to retrieve models from the database and interact with these.

3.1 Programming Tools
The entire modeller works over the Internet and, is therefore written, using languages that can be read and interpreted by common browsers. The main part has been written in VRML (Virtual Reality Modelling Language) and VRMLScript. Other languages and file formats used are HTML (Hyper Text Mark-up Language), PHP3 (a scripting language called Professional Home Pages Version 3.0), JavaScript, Java, EAI (External Authoring Interface) and a MYSQL Database.

From a system point of view, first one submits a form with the name of the user. This form is embedded into an HTML page, with a JavaScript program checking the user's input.

This form is then send to the server, where a PHP3 program parses the name into a VRML file. The user receives an HTML file with both a VRML file and a Java applet embedded into it. On the client side of the connection, a browser, in this case Netscape Communicator 4.04 with a VRML Browser plug-in (Cosmoplayer 1.02), displays the VRML World. Through the EAI Interface the Java applet reads and writes data to the VRML scene and communicates this information through a JDBC driver to a MYSQL database. [Figure 2]

3.2 The Interface of the Modeller
The entire program is displayed in one full-screen window. The VRML scene takes up the full window and the complete menu of the interface is programmed inside VRML as a HUD (Head Up Display). It is divided in two horizontal rows of buttons on the upper and the lower part of the screen.

The menu of the upper part controls the modelling features; modelling is done locally on the machine. The menu on the lower part allows to connect to the database, in order to submit the work or retrieve objects for interacting with these. In order to make the interface comprehensible, the menu is reduced to the essential elements.

3.3 Modelling Tool
The modelling process is handled in two separate phases. These phases are called the InWorld and OutWorld modus. The InWorld modus controls the location of cubical forms within a grid structure, while the OutWorld transforms the grid structure by applying forces onto it.

In a first phase, cubes can be placed, moved and deleted within a frame structure of $7 \times 7 \times 7$ units. To place new cubes in the grid one needs to click on a face of a cube. Afterwards, by dragging the mouse, it is possible to place new cubes into the grid structure in the same plane of the face clicked. To move cubes inside the grid, a similar mechanism is used. One needs to click on a face and drag the mouse. The cube will follow the mouse in the plane of the touched face. A collision detection mechanism controls this process. As such, it is possible to move a whole row just by pushing on one end. [Figure 3]

The second phase consists in the deformation of the grid structure. By activating the OutWorld modus the buttons in the upper centre switch to enable the OutWorld transformations. In this phase one has to select a part of the grid structure. For the selection, the grid structure is always displayed in an orthogonal way. The selection box is displayed in red. Once a part of the $7 \times 7 \times 7$ grid has been selected, one can apply either a translation or a scaling transformation to the selected part. To apply a transformation one needs to activate the transform button. Subsequently, a deformation takes place by clicking on the selection box and dragging the mouse while being clicked. When the mouse is released a process recalculates the grid structure. As in the first phase, the translation is applied on the plane of the touched face of the selection box. [Figure 4]

It is always possible to switch between these two modes. Whenever the InWorld modus is selected, the whole scene is displayed as an orthogonal system. This system is more appropriate to control the placement of cubes inside the frame structure. Working in the orthogonal and transformed view allows a better understanding of the modelled object. The orthogonal view is well suited to understand the structure of the model, whereas the transformed view is obviously needed to control the shape of the form.

3.4 Interacting with the Database
In addition to the local modelling process, one can load the last three models from the database into the working environment. To display these objects, the left and right button from the lower menu open an iconographical view of these elements. On the left side the InWorld and on the right side the OutWorld views are displayed. To interact between the local model and objects from the database one only needs to click on the icons. By clicking on the InWorld icons a substitution takes place. By clicking on the OutWorld view a transformation process starts which morphs the actual grid structure into the grid structure of the object from the database. [Figure 6]

In figure 5 three different diagrams of work processes are shown. The first diagram shows the situation of a traditional way of working with a computer. A very strong relationship is established between user and computer. In this way nearly no communication takes place between different users. The second diagram shows a first step towards collaborative work. The user is still working with a local file. Only in a second step he submits his or her work to a database. This mode already allows a certain level of interaction. The third diagram illustrates that the user is no longer working with a local file, instead, submits his or her work directly to a database. Whenever an object has been submitted to the database, it can be seen by any other user.

4. Conclusion and Future Work
Although scripting languages are supposed to be slow and ineffective, this modeller written in VRML is surprisingly fast and stable. Using the computer knowledge background of an architect, VRML has been an excellent way to dive into 3D programming. Looking at the actual situation of VRML and the capabilities of Java3D as an API, this work has arrived at a point where it seems advised to port it to Java3D.

The modeller is quite powerful but has only very few modelling possibilities. An important task will be to find new features, to enhance the tool without making it too complex to use. An interesting feature from Java3D are the input possibilities. Finding an adequate input device other than a mouse or a joystick will make the modelling task a lot more intuitive. Until now the user is constrained to work in a grid of 7x7x7 units. It would be interesting to add a second level into the modelling process, so that once cubes are placed into the grid these could be substituted with more complex objects. The database has a very rough interface at the moment. Although lots of information is collected, no intelligent way of browsing the database is available. For future work, the database should allow for retrieving objects by completion time or by author as well as displaying the relationships between the objects. An important issue will also be to allow more than one person to work simultaneously on the same model.

5. Acknowledgements
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6. References

AUTOMATION OF DECK BRIDGE REPRESENTATIONS

AUTHORS

A. Almeida Sampaio
Civil Engineering Department
Technical University of Lisbon
Av. Rovisco Pais
1049-001 Lisbon, Portugal
zita@civil.ist.utl.pt

ABSTRACT

The bridge deck has a apparent simple shape, but it is the result of an adequate combination of two longitudinal geometric components: the deck shape evolution along de longitudinal section the layout of the road, that acts in simultaneous over a cross section, defining the deck exact shape. A geometric modelling computer programme was developed for box girder decks, allowing the generation of cross sections along the deck, defined with correct shape and location.

In the elaboration of the deck plan drawings, the geometric information of the real deck shape is required. This information is not managed in an integrated and automatic way. On the creation of these drawings, directly executed over a graphic system, the time consumed is considerable and it is easy to comet errors.

This paper describes the drawing module included in the computer program refereed. The deck plan projections are obtained, in DXF format drawing files, using the geometric information obtained from 3D-deck model. Using the drawing module it is possible to generate the usual deck drawings required in bridge design process. Then, this module is a great support for the design process within its geometric design stage.
AUTOMATION OF DECK BRIDGE REPRESENTATIONS

1. The deck configuration
The surface shape of the deck can be seen as generated by one cross section that crosses the longitudinal direction. In that trajectory, the cross section configuration is modified in function of the two longitudinal morphologies:
- the morphologic evolution established by the bridge designer;
- the layout of the road, where the bridge is inserted, geometry that the deck must adapted.

The concept sweeping representation of the deck ([Anand,93], [Woodwark,86]) by means of a cross section shape that crosses a longitudinal trajectory, analytically defined, was implemented in a computer programme oriented to box girder decks [SampaioA,98]. This programme was developed in the ambit of the PhD thesis effectuated by the author [Sampaio,98].

1.1 The deck shape database
The deck geometric modelling programme allows the definition of the exact deck shape by the geometric description of the three morphologic components of deck configuration. A representative deck shape database is, then, created (Figure 1). This database allows the integration and automation of bridge design stages, based on the deck shape geometric information. The programme generates cross sections along the deck, manipulating directly the data of the geometric database.

![Diagram of deck shape database]

Figure 1: Creation of the deck shape database.

1.2 The deck geometric model
The longitudinal morphologic components referred act in simultaneous over an initial cross sections when it crosses the longitudinal direction of the deck. This is executed in two sequential phases:
- The cross sections are generated along the deck only in function of the longitudinal analytical laws of variation established by the bridge designer. Those laws are refereed to the deck depth variation and to the flanges thickness variation (upper and low flanges and webs). In these phase it is admitted that the deck is straight and horizontal;
- Then, each generated cross section is submitted to geometric transformations in its own support plan. Its forms are adapted to the required superwidth and superelevation in the kilometric point corresponding to the cross section
location. Later on, the cross section is transformed as a rigid body in order to be localised and oriented in correct way in a spatial trajectory defined by the horizontal and vertical alignments.

Then, the computer programme allows the creation of a geometric model of the deck formed by a series of consecutive cross sections, correctly defined in configuration and spatial position (Figure 2).

Each cross section is defined in vertices spatial co-ordinates format file.

![Figure 2: Deck geometric model formed by a series of consecutive cross sections.](image)

2. The drawing module

The drawing module, included in the computer programme, can allow automatically the deck drawings and the 3D face model usually required in bridge design. The geometric information of the cross section series, generated along the deck, is required.

The cross section data files of the are used on deck drawing elaboration. The drawing module manipulates directly the vertices co-ordinates of each cross section outlines, in order to obtain the required deck geometric models. Each representation type presents the deck shape in a particular way.

The drawing module creates the deck representation in DXF format file drawing [Jones,91]. It is, then, possible to visualise the respective drawing, when the file is inserted in compatible graphic systems (for instances the AutoCAD system [AutoCAD,97]).

3. DXF format

The DXF (Drawing eXchange Format) files were defined to allow the transference of drawings between AutoCAD and others CAD (Computer Added Design) systems or data process programmes. The graphic systems usually used have the capacity to generate and to interpret DXF files. The DXF format is an ASCII (American Standard Code for Information Interchange) text format, of easy interpretation by the user and others computational programmes.

A drawing file in DXF format can be defined in complete way, composed by four types of graphic characteristics, or it can be formed only with the graphic entities definition. When complete, the tree first sections define: the drawing ambience (HEADER SECTION); the layers characteristics, type lines, styles, etc. (TABLES SECTION) and the blocks definition eventually used in the drawing (BLOCKS SECTION). The entities definition of the drawing is include in the last file section, the ENTITIES SECTION.

Then is, exclusively, the last section that contains the information needed to visualise the representation include in the drawing file. The entities section
describes, in DXF format, all the graphic entities of the drawing. One entity can be a line, an arc, a polygonal line, a text, etc. The drawing module creates deck 2D and 3D models defined in DXF format files composed, only, by the entities section. There are established schemes of execution of the specified models based on the selection of several entities that in conjunct define the refereed drawings. In each case the entities are concretised with the data include in the cross sections files needed on the execution of those models.

4. Algorithms of deck models automatic execution
Based on the observation of box girder deck drawings included in several bridge designs, was possible detect some uniformity on the presentation of the principal deck plan projections and deck 3D model. The common characteristics founded, are included on the definition of the programmed drawing-standard established for each representation type.
To execute a cross section representation, the cross sections transformed only by the incorporation of the superwidth and the superelevation, is needed; on the definition of the deck longitudinal section, over those cross sections is needed to impose the vertical alignment geometry.
The bridge is a structure that interferes on its landscape, having style and particular characteristics that must be in harmony with the local environment. Then, its appearance and insertion in the existent ambient must be considered of the aesthetic point of view, since the first design stage. The bridge is a 3D-structure and, then, the aesthetic conceits must be contemplated from any point of view.
One of the most used process to create deck 3D models, is to generate cross sections along a spatial longitudinal trajectory (defined with the horizontal and vertical alignments of the road geometry information), iby interpolation between control cross sections, using B-Spline surfaces. The generated cross shapes are, however, approximation of the deck cross section shapes, its orientation is normal to the trajectory and only the exterior view is allowed.
With the drawing module, here presented, is possible to visualise the deck 3D shape, composed with cross sections of correct shape, location and orientation. The deck 3D model is formed by a sequence of plan surface elements (3DFACE). This model can be submitted in graphic system to a several realistic algorithms (faces and edges elimination and colour application), conferring the model a solid aspect.

4.1 Cross section representation
Next is described how to create the DXF file drawing of a cross section. As only the entities section forms the drawing file, the first data to put into the file drawing corresponds to the beginning of a section definition.

0
SECTION the beginning of a section definition
2
ENTITIES section identification

The DXF format of an entity has a constant structure. Only the numeric values are different between concrete cases. Then the drawing module has one
routine for each entity used in any programmed representation. The routine of an entity defines the geometric parameters with the numeric values and places this information, in the DXF format [Jones,91], into the drawing file. To define the outlines of cross section the graphic entity used is polygonal line entity (POLYLINE, in AutoCAD [AutoCAD,97]). It was established that the outline of a cross section should be formed by four open polygonal lines defined with the vertices plan co-ordinates included in the respective cross section file. The definition of each polygonal line in DXF format is placed in the drawing file by means of the respective routine. The DXF format of a POLYLINE is as follow [Jones,91]:

```
0
POLYLINE entity identification
8
0 layer identification where the entity is located
66
1 vertices definition is following
70
0 definition of a open polygonal line
0
VERTEX element identification
8
0 layer identification where the vertex is located
10
x_p(1) x co-ordinate value of the first vertex
20
y_p(1) y co-ordinate value of the first vertex
0
VERTEX
8
0
10
x_p(2) x co-ordinate value of the second vertex
20
y_p(2) y co-ordinate value of the second vertex
...
0
SEQEND end of vertices definition
8
0 layer identification where the element is located
```
The x and y co-ordinates of each POLYLINE vertices were defined, in the routine, as variables \( x_p() \) and \( y_p() \). The co-ordinates of the cross section to represent assume in each case the values of the variables. The location order of the vertices in file indicates the vertices topology. The definition of all graphic entities, that identifies the cross-section shape, is followed by the end section and the end file information. Is possible now to visualise the cross section representation. For that, the drawing file in DXF format should be inserted into a compatible graphic system.

The module of cross-section drawing definition also places into the DXF file the definition of the symmetric symbol and inserts the kilometric location over the cross section representation (Figure 3). The LINE entity (of AutoCAD) represents the symmetric axe. The drawing module includes a routine with the definition of the entity LINE in DXF format [Jones,91]. The upper symmetric symbol is defined by two open polygonal lines composed with four vertices each one. The kilometric value (that locates the cross section into the road) is represented by the TEXT entity (of AutoCAD).

![Figure 3: A cross section representation.](image)

4.2 Longitudinal section

The longitudinal representation is another usual deck plan projection included in a bridge design. In the representation the longitudinal outlines are complemented with the information of cross section kilometric location, the elevation value related to the deck axe and the dimensions of the flanges thickness and deck height, in each cross section used to form the drawing (Figure. 4).
The longitudinal representation drawing file includes to parts: the longitudinal outline definition and the text dimensions.

To create the deck longitudinal section, the deck must be submitted to a longitudinal section executed by a surface that contains the deck longitudinal axe and symmetric axes of each cross section (Figure 5a). Later on, that surface is planed in order to obtain the pretended plan projection. The longitudinal section is represented with the longitudinal edges resulting of the intersection of the deck with the section surface and with the longitudinal edges that is possible to visualise over the section surface.

The graphic entity used on longitudinal edge representation is, also, the polygonal line entity (POLYLINE). Each polygonal line is formed with the vertices in equal number of the cross section involved in the representation. The co-ordinates values included in the cross section files are used to define the required polygonal lines, in the DXF format. The intersection zone is identified with its outlines detached from others lines of the drawing with different colours. In the DXF format of the used entities the group with the 62 code number (refered to the colour) is associated with distinct values for the definition of lines in intersection zone or lines visualised. In the definition of the longitudinal representation each cross section is represented by a LINE entity [AutoCAD, 97], oriented in a vertical way. To put the text dimension in a drawing, include the definition of the dimension lines, the extension lines, dimension limits (donuts, arrows or oblique segments) and the dimension numeric value. The dimension values, included in the drawing represented in Figure 4, are calculated in function of the data of the respective cross section file.

4.3 3D surface model

Using the deck geometric modelling programme, several solutions and redefinition of the deck shape, can be visualised from any point of view and in a quickly way. Following the shape definition stage with a dynamic visualisation, anaesthetic forms can be avoided.

The graphic entity used to represent a plan surface is the 3DFACE entity (of AutoCAD [AutoCAD, 97]). The co-ordinates of four vertices that define this entity must be in a spatial referential. The vertices sequence must follow a circular order. Two consecutive vertices, of equal number located in consecutive cross sections (Figure 6) limit each plan element 3DFACE. Each entity, formed by four vertices, is included in sequential order in the drawing files, in DXF format [Jones, 91].

Figure 4: Longitudinal section detail.

Figure 5: Process to obtain the longitudinal section of a deck segment.
Figure 6: Definition of a 3DFACE entity between two consecutive cross section.

The model, defined with those plan elements, form two longitudinal tubular surfaces representing the exterior deck surface and the interior deck surface (Figure 7 a). It is necessary to define as surfaces the top cross sections in order to obtain a 3D model with a solid appearance (Figure 7 b).

Figure 7: Deck segment 3D model without (a) and with (b) top cross sections defined as surfaces.

The 3DFACE entity also represents the top cross sections of the geometric model. Each surface is defined with an adequate triangulation formed by those plan elements. Defined both top cross sections as opaque surfaces, for any point of view established the created deck 3D model seems like a solid object, after insertion the respective DXF file into a compatible graphic system.

The principal interest of this geometric model is, naturally, to allow the visualisation of the complete bridge with a real aspect. Generated the 3D model faces DXF file of the deck, using all the cross sections needed to the elaboration of all deck extension, it can be complemented in the graphic system, with other structural elements and bridge details (Figure 8). The abutments and the piles have usually specific shapes in each case.
5. Conclusions
The purpose of this paper was to present the developed methodology to achieve the automation of the required deck models in a designed bridge. The algorithms presented use the graphic information related to cross sections generated along the deck with correct shape, location and orientation. With those algorithms is possible to create:
- deck cross sections representation;
- deck longitudinal section representation with the indication of dimensions, elevations and kilometric values;
- deck 3D face model
Using the deck geometric modelling programme (described in [SampaioA,98] and [Sampaio, 97]) is possible to obtain in a quickly and correct way the deck representation need in bridge design. With this programme in possible to reduce the time consumed in the execution of a bridge design. It is, then, a great contribution to the execution of the geometric stages included in a bridge design. It is also an incentive to do several iterations of the deck shape in an initial design stage, since the aesthetic aspect is a decisive factor on the selection of a solution for the deck configuration.
6. References


1. Introduction
Facilities Management (FM) can't be seen as a subject with a specific area of knowledge with exactly defined borders relative to other subjects. Analysing the economic aspects of FM leads to the realisation that building management is experiencing a process of increasing specialisation and professionalism. It is possible to define FM from a variety of different points of origin. One possible approach views FM as an integral solution for the administration of buildings, their commercial activities, and technical maintenance from an economic perspective, during the whole life of a building. FM covers all strategies in order to efficiently provide, adequately operate and adapt buildings, their contents and systems to changing organisational demands. The current practice of limited analysis of specific administrative aspects, e.g. maintenance, is replaced by consideration of all factors that affect costs. Since all costs can be directly traced to space, the perfect procedure requires that FM is practised during the whole living-cycle, starting with the definition of the program of construction until the day of conversion or demolition. Through successful FM, the real estate can contribute decisively to the improvement of productivity and the quality of life.

2. Understanding and necessity
Unhappy employees, high costs of maintenance, inflexibility, the waste of space, these are just a few building administration problems that, if not already present, creep in over the years in the absence of proper control procedures. FM computes the building as a whole, in all its administrative aspects. FM allows a transparent, comprehensive analysis, and provides easy approaches to costing, presentation of a variety of data and visualisation of yields and expenses in meaningful ways.

For decades our market-based economy has driven all areas of the economy toward optimum utilisation of resources. Robots, computers, lean production, home offices, electronic-commerce and many more achievements are tools to lower expenses and enhance products and productivity. However, the economic sector of real estate management seemed, until recently, to have
escaped the pressures of economic efficiency. Only a few years ago, real estate project managers identified real estate management, in all its aspects as an area that must find ways to lower costs. FM is the tool to transform the frequently inefficiently used buildings, which tie up massive amounts of capital, into resources responsive to the new demands for flexibility, profitability and humanness. The future demands an efficient utilisation of real estate resources and thus exerts pressure to implement FM techniques. A recent study conducted by IFMA (International Facility Management Association) of several U.S. corporations showed that 25 to 50% of business capital balance sheets and 10 to 18% of business profit and loss accounts, can be directly traced to costs of owning and operating both real estate and buildings.

3. Significance and impact on the student
As demand for FM-specialists is on the rise, students have to be prepared to cope with the challenge of the subject FM. Especially a student of architecture who nowadays faces difficulty finding a proper job, FM specialisation would dramatically improve the potential for personal professional success. In addition, in the future it will be more important for architects to consider economic aspects of their projects. The European competition necessitates, already during the early design stage, provision of solid financial statements for the building to the investor, encompassing the entire period of use. As a result architecture students of today need all possible tools at their disposal to be able to predict the future evolution of their realised designs. Only an expert in all these fields will be able to successfully attract big contracts.

4. Significance and consequences for the educational system
Universities need to prepare students by providing all knowledge relevant to their later professional success. FM has to be integrated and taught in combination with the related subjects. For the AVOCAAD project an integration into the existing teaching areas is useful and attractive at the same time. The AVOCAAD scheme and the involved structures of exercises were publicly discussed for the first time at the 1998-ECAADE Conference in Paris by Verbeke [1]. FM is a recent, fast expanding topic and lends itself particularly well to interactive web instruction. The web is the most recent relevant media evolution which provides the user with an ability to cope with rapidly changing contents and structures at very low costs.

5. Realization of an online exercise
The exercise could be structured into different levels of

- complexity
- overview/detail
- demands (industrial/domestic)
- interactivity (reference/training)
- and alike.

The following figures show an interactive result-page. Interactive exercises and the theoretical background of executing on-screen interactivity are presented in a separate paper on this conference by Sprekelsen/Pittioni [2].
The exercise aims to demonstrating the behaviour of the relations between the costs invested in the building and the maintenance-costs, giving the overall investment after 10 years. We have simplified the very complex relations between building-costs and the expected maintenance-costs to a very high extent. Otherwise it would exceed the nature of a mere demonstration substantially.

Figure 1: AVOCAAD exercise, FM-training. Building costs at very low level.
Figure 2: AVOCADA exercise, FM-training. Building costs at higher level. Maintenance-costs will decrease substantially.

The overall investment will become minimised at a certain relation between the original investment into the building costs and the maintenance costs. These costs depend from the standards chosen and a number of other factors. This relations can be studied by changing on-screen the first element of the diagram (the building costs), so that the overall costs tend to minimise. See figure 3 – the algorithm operating the relations between the cost-factors show minimum overall costs at 38% building costs and 62% maintenance.
Of course this behaviour will vary with regard to the special kind of buildings, as the dependent parameters will change their values. Anyway, this example should show the general functionality, moreover it is a good demonstration of interactivity within AVOCAAD exercise sheets.

It was positively the intention to avoid complex structures and dependencies to focus merely on the functionality. To obtain this we focused on the following main features:

- simple structure
- easy to understand / intuitive operation
- stress on the content
- real-time interactive exercise simulation, where results can be graphically demonstrated and correlated with user-initiated changes of variables
- tuned on graphical output

It would be a very nice exercise of its own to develop functions which represent the relations dependent on different building usage.

6. References


AVOCAAD EXERCISES
EXPANDING ON INTERACTIVE OPERATIONS

AUTHORS
Martin Sprekelsen
neue Rezepte
Föhrenstr 13a
D- 82194 Gröbenzell
martin@neueRezepte.de

Gernot Pittioni
Ingenieurbüro Pittioni
Pipinger Strasse 102
D- 81247 München
pittioni@pittioni.de
AVOCAAD EXERCISES
EXPANDING ON INTERACTIVE OPERATIONS

Contents
1. Introduction
2. Advantages of interactive web-pages for AVOCAAD
3. Technical survey
4. An example
5. Outlook
6. References

1. Introduction
The web is a vital element for realising the AVOCAAD project. The web's features and functionality present a splendid platform. The following will discuss multiple advantageous options available through this new media as they relate to the AVOCAAD project.
All data are permanently available on a central server, accessible to an unlimited number of clients anytime, anywhere in the world. Clients access the centrally stored information and work locally with the material, thus using the common server-to-client publishing set-up. Dynamic database functions available to the general user are able to control various aspects of data flow. This procedure is used by the AVOCAAD-web-system. Recent developments in the web are going to enable an even more sophisticated use, thus widening the range of application. The online material may present interactive properties, meaning that the user is able to observe changes of processes in relation to the influence he actually exerts on the material within his subsystem. We will focus on this material in our paper, exploring the possible impact on AVOCAAD-exercises.

2. Advantages of interactive web-sites for AVOCAAD
The AVOCAAD-exercises offer a professional aid to students and architects looking for training material. The structure was shown by help of some examples 1998 by Verbeke [1]. In general, AVOCAAD instructions are provided in a problem-solution or knowledge-transfer format. As in all systematically performing processes, in special cases, e.g. structural design, the need arises to show or observe the solution process. The learning process can be made more efficient by interactively demonstrating the behaviour of systematic or procedural exercises. Thus the user experiences solution possibilities by determining a varying range of control options. Solutions will rarely be stringent as to the way they are achieved; this is even true for engineering problems. For example, one can improve the energy-behaviour of a building to a given extent by insulating either the roof or the walls. The process of developing optimal potential solutions would be explained most clearly to the user by allowing him or her to
alter specific parameters and observe the corresponding changes in numeric process behaviours and outcomes.

In addition there are cases where the common "description – goal – exercise"- scheme does not work efficiently, for there are a number of sub-solutions, each exerting their own specific influence on the remaining solution process. Imagine an exercise with a result consisting of different steps, and a non-linear structure; the goal defined as the correlation between these working steps. A meaningful instructional exercise exhibiting this level of complexity will be highly dependent on the interactive functionality of the web page. Thus an individualised solution can be achieved by guiding the user interactively.

Finally an exercise might present a general concept within more relaxed limits which enable the user to work with details according to the individual level of knowledge and/or interest.

3. Technical survey

The tools to provide web-sites with interactive properties are currently in development. As web-technologies (for example the document language HTML) are in a constant process of evolution, new developments arise, thus expanding possibilities.

One problem in this evolution-process is, that usage patterns of different browsers vary widely; those familiar with web-browsers will confirm that the support of the latest web-features is not guaranteed with all browsers. Sometimes browser graphic presentation differs substantially from the intention of the web-site-developer. This difficulty will grow even more as tool sophistication increases. Therefore it is generally highly recommended to use only those language-definitions which are commonly accepted by different browsers; in particular this refers to language definitions standardised by the www-consortium\textsuperscript{1}.

In the context of these restrictions, the following options to develop a web page exist currently:

\begin{itemize}
  \item The Document Language Enhancements DHTML (dynamic-HTML), DOM (document object model) and XML (extensible markup language)
  \item The Script language ECMA-Script, the former JAVA-Script
  \item JAVA, the Web-programming language
\end{itemize}

All these systems have in common that they are supported by the two most widely used browsers, Netscape Communicator (Navigator) and Microsoft Internet Explorer (at this time only beta versions of DOM and XML exist). The Document Language Enhancements aim at basic definitions of how to handle a certain page on-screen. The web-page is handled as an object with properties and functions – not as mere document presentation. Thus the web-page offers the functionality to be handled like a program, so mouse-operations and similar input can be interpreted interactively. User-initiated change of parameters is easily accessible on-screen.

JavaScript exists as a script-language, which was originally developed by Netscape. In the meantime it is officially acknowledged as ECMA Script by the W3C-Consortium. It was integrated (more or less completely) by Microsoft into its Internet Explorer as JScript.

\textsuperscript{1} An international commission, also called W3C. Since 1994 it oversees the development of the www-standards; its decisions are used as guidelines by developers all over the world.
ECMA Script resp. JavaScript resp. JScript offer an object-oriented structure – more or less completely – and thus handle
• mathematical operations
• string-operations
• parametrical processes
• user in- and output and
• browser-related functions.

A conceptual weakness of the Script-language is its inability to change web page source code interactively, once the page is built-up. That means that we have very restricted output-properties, except for HTML-forms, graphic objects, or browser-owned elements. In connection with DHTML or DOM this weakness is omitted, the web-page is entirely controllable. Script-languages have the benefit that they can be written directly into the document-source-code. This makes programming easy and processing-time is enhanced considerably, as no additional modules or libraries have to be loaded.

In certain cases it will be inevitable to use a genuine programming-language as Java, to avoid the mentioned weaknesses. Java is a completely object-oriented language, which is closely related to the programming language C++. The former – Java - was developed by SUN Microsystems, Inc., for use in the world-wide-web.

Currently Java source code is freely accessible, which guarantees its further existence and development. By choosing Java the programmer has definitely all properties of a highly sophisticated programming-language at his disposal. The transmission of lean precompiled source-code over the net ensures satisfactory performance on all systems in most cases, assuming availability of a runtime-version of a compiler. This independence of the platform in actual use is both an advantage and a disadvantage, because the applets - the loaded and processed Java-programmes – considerably slow the performance of the web-page.

Assuming those "teething troubles" will be omitted in the near future by use of optimised compilers and by general progress, the programming of highly-sophisticated interactive web-pages will become more and more attractive. This will enhance the added value of AVOCAAD-exercises considerably.

4. An Example

In order to demonstrate the theoretical background we will proceed with a demonstration of the features by selecting a very simple topic.

In Figure 1 we can see an interactive Exercise, where a student can visually experience the influences on the energy consumption of residential houses by changing different parameters, like the thickness of the walls or the size of a window or the conductivity value of the insulation. It's a great help in understanding the energy behaviour by interactively testing the correlation of parameters.
Another interactive exercise which is going to be shown in the course of this conference is the facility management diagram included in the paper of Oswald, Pittioni [2]. These exercises are written in JavaScript, which controls the in- and output of the text-fields and naturally also performs the correct mathematical calculations.

5. Outlook
Looking at the future, it is likely that AVOCAAD-exercises will increasingly take advantage of interactive web-page features. The combination of server system functionality with client system functionality, as discussed above, will likely become highly attractive.

The guiding of the user - during the processing of his exercises - and the further processing of the results by the central server-system will increasingly operate together. For the end-user web-page interactive functionality will become ever more important.

6. References
AVOCAAD – EXERCISES
EXPERIENCES WITH TESTING

AUTHORS
Helga Rosenbauer
Glasenbartelstrasse
81247 München
freelance architect at Ingenieurbüro Pittioni, München
h.rosenbauer@pittioni.de

Carena Dallabetta
Architekturbüro Peter Kupferschmidt
Widenmayerstrasse 18
D-80538 München
AVOCAAD – EXERCISES  
EXPERIENCES WITH TESTING

Contents  
1. Introduction  
2. Intention of paper  
3. Looking out for good exercises  
4. Giving evaluations  
5. Conclusion  
6. References

1. Introduction  
We architects in general do not tend to exhibit an irresistible urge to use modern media. However, we at least live and work within a constantly expanding environment of contrasting elements: Buildings tend to get more complex, prices tend to go down and honorariums desperately tend to decrease at the same time. The industry is busy promising us architects that we will only survive this scenario by using excellent computers with outstanding CAAD-software-products. This aspect is crucial. No architect who is forced to earn his living by handling the daily mess consisting of  
• contacting clients  
• calming down contractors  
• speeding up planning partners  
• keeping the own design business running  
will be able to view his computer as a toy, but rather as an important ally. Our knowledge and areas of interest will be clearly confined by aspects directly connected with our daily exercise of professional activities. Of course we architects are increasingly forced to use better means of presentation. And we are forced to present our design  
• with growing accuracy  
• within less time  
• and offer a high-level compatibility with the CAD-products of the planning-partners.  
This again means that we need constantly improving tools.  
Who is developing and providing these tools? And how do we architects get our training to handle those improving tools?  
Let us first focus on the development of tools. Software-companies have identified this market years ago. Architects will survive on the battle-field of competition only by using efficient software tools. If there is a powerful user-group there is a good chance to exercise significant influence and even pressure on developers. User-groups in our days need not gather physically in time-consuming conferences, they can easily stay in contact using modern communication-media like internet-forums or e-mail. Somebody has to collect e-mails and can provide a powerful summary, based on a large number of users, which is presented to the software company.  
This software provider is directly dependent on the satisfaction of the users, otherwise they will eventually – even very probably – change to another
provider. This is getting easier and easier in our days. No one is actually forced to stick to specific software, because one’s hardware is able to meet any special software needs. This situation of software-dependent hardware conceptions was very common in the past. Thus the software developer will offer a very attentive ear to a powerful user-group.

Next are the schools and universities, which provide a good amount of testing and training capacity. They will be predestined to develop training methods for practising architects unskilled in CAD software use.

2. Intention of paper

These training materials are the main aim of the AVOCAAD-project. Inserting a simple CD-ROM and going through some exercises or alternatively using the internet for the same purpose is exactly the way to attract professionals pressed for time.

What are architects – practicing architects – expecting from training materials, such as AVOCAAD is in the process of developing?

In our days no architect will honestly fight the usefulness of computers. We can assume that most of us architects have understood that computers are not threatening the quality of architectural design but improving it considerably.

The data-interface to planning partners, clients and contractors is an important element of powerful interaction in our days. This is only possible by using computers. If there is only one single planning partner who is not referring to the common data base, the whole system is broken.

The planning time can be reduced considerably by using computers. None of us architects will be able to survive on the free market in the long run, if he or she denies this development and goes on fighting the traditional way, sticking stubbornly to paper and pencil. Some twenty years ago the same thing happened to computer-abstinent engineers.

Thus it is a feasible assumption that we can rely on getting efficient and cost-effective support through use of computers. And there is a good deal of progress in store, looking at present and future aspects by the growing impact of Facility Management [1].

There is one thing that is very important to us: Many architects active today have learned their design process manually. They were crouched over large drawing tables and did their work using traditional tools more or less enthusiastically. When these architects change their tools to mouse and computer screen they tend to stick to their traditional methods without taking advantage of the new powerful tools which are structured completely differently. This needs to be addressed with training, or else a significant disappointment cannot be avoided.

In addition we cannot assume that all schools of architecture are able to present good teaching personnel. This is not only a question of money – meaning adequate payment of teachers. A student who uses a powerful computer with any powerful CAD software will very soon end up with photo-realistic images of his or her design instead of getting a profound training in preparing a correct - and we really mean: correct - set of 3D-data of his or her design within a reasonable time. This means learning all advantageous aids or added values of CAAD, which are mostly independent of the software used.
3. Looking out for efficient training material
Training material which is useful for practising architects preferably refers to the improvement of efficiency rather than to time consuming features such as
• Rendering
• Photo-realism
• Virtual Reality
This does not mean that we architects do not want to be taught these topics. There is a growing need for outstanding quality of presentations; this again is offered by modern software on highly efficient computers, which can be bought for ridiculous prices, compared with the situation only a few years ago. If there is going to be a software aid providing ideas for studio-activities in early phases of the architectural design -- a development likely in the near future -- most of us architects would stick to sketching on paper anyway. Really efficient software covering this field must provide excellent training – possibly through entirely new methods.
Efficient training material will provide, whenever possible, a complete survey of a topic or theme. A selective exercise which only covers a very restricted field of an entire curriculum will be possibly interesting, but could not yet provide the full power of submitting the added value of a new tool.
Efficient training material will provide help-functions, and will also give handling advice even on low level features.
Efficient training material will give an example - or even several of them - to make sure that the exercise at issue has been approached correctly. A possible objective of the example would be to overcome language-problems. In addition, we may assume that examples can bridge differences in curricula. Of course it has to be discussed how far a rather primitive introduction into CAD-handling should be involved. There are numerous experiences with partner offices where we can find persons who are very willing to become familiar with CAD-handling. In some cases they are very far away from accepting the value - not even to speak about an added value - of CAAD. In our view efficient training material should cover even these basic needs.
To guide persons who have been working with traditional tools to CAAD presents a very special challenge. If someone is very skilled in the traditional way of handling all drawing and designing activities, it will be rather difficult to convince this person of the values of CAAD. For a rather long time he or she will initially not only be much quicker working the old way, even worse, he or she will use CAD in a wrong way by transferring the traditional way of working to the new tool. This will rarely produce a satisfactory result.

4. Giving evaluations
There are not many exercises available for testing. In general we refer to the paper of Verbeke [2], where we can find the characteristic features of the planned structure.
At the start of an exercise we would appreciate a nice explanation of what we are supposed to do. Sometimes there is an obvious dependence on unfamiliar curriculum. Especially newcomers might be unable to continue or finish certain exercises.
Generally everything that is mentioned above under the section covering the efficient training is good for giving an evaluation. This means that exercises providing sufficient help-functions and information features examples - if possible - that are rated 'excellent' in order to give some support how an exercise is to be understood in cases of language problems a background survey of the training field, which may lead to packed information on whole curricula have a very good chance to get a good evaluation by users, especially by those not belonging to universities.

Figure 1: AVOCAAD exercise sheet; links to “submit” and “other results”.

The planned structure of the exercises (see figure 1) shows the possibility of submitting results. More than that, we guess that we shall be able to compare our results with those found by others. In addition a teacher's comment would be a wonderful help.

To us practising architects it seems extremely important to really get help from computers. This help is not only supposed to speed up our daily activities but also to enhance the quality of our work. We are confronted with results of planning partners who pretend to be familiar with CAAD. Especially the detail level tends to reveal deplorable facts. In particular, if the design task at hand is part of a major planning context, it is rather difficult to integrate contributions of poor quality.
Reviewing plotted output does not shed much light on the quality of the data structure. Nobody can see how nicely the layer discipline was observed, only after, for instance, moving the furniture layer to the background we may detect how many walls and windows are vanishing together with the furniture. Taking measurements between certain construction points will reveal unclear definitions, which are not obvious by only looking at a nicely plotted drawing. All this is rather trivial matter but this only demonstrates how important it is to have a sound instruction on CAD basics. We would very much appreciate if the AVOCAAD material also gave us some training in very basic CAD topics. At least this should be discussed, though AVOCAAD is focusing on the added value of CAAD.

5. Conclusion
We are very glad that in the near future AVOCAAD will be offering training material for those architects willing to go into CAD activities. We know that the main effort will focus on university activities. But we think that there is an outstanding chance to involve architects outside of universities. While it is extremely difficult to convince them initially of the value of CAAD -- not to speak of the added value -- in most cases financial or economical reasons will be the only motivator.

We have also tried to point out how to define efficient CAAD training material. Above all we are aware that everything we have presented in this paper might originate from a rather specific perspective of the subject. In general the AVOCAAD project will aim to support university teaching. Nevertheless many of us architects who are in practice for years and even decades, might gladly seize the chance of exercising with training material, which enables us to develop and implement whole new capabilities we had no chance to achieve in our studies.

6. References
BENEFITS OF DATA INTEGRATION IN BUILDING MODELLING:
3D OBJECT ORIENTED PROFESSIONAL COLLABORATION

AUTHORS

Kokosalakis Jen
Liverpool John Moores University and School of Built Environment
Clarence Street, Liverpool, L3 5UZ, UK
j.kokosalakis@livjm.ac.uk

Hohmann L.M.
‘The User Group’ Chair
lmh@globalnet.co.uk

Pamplin I., et al.
‘The User Group’ Secretary
ian@pamplinass.source.co.uk

ABSTRACT

This paper will review current progress across the building construction industry in meeting demands for use of data integration with the 3D building model as the coordinating device in building design and development. Decades of national initiatives from NEDO (1990) to Egan (1998) have striven to encourage collaboration in first the building design team and later targetting in programmas the means to accomplish this. In its 14th year ‘The User Group’ has intensified efforts to persuade the industry of the benefits of associating all data involved from the first briefing and conception of design needs and ideas, through the development of the design, testing for structures, costs, heating, lighting, urban and rural environmental impact, facilities management, adaptation and even the eventual controlled demolition of the building. Examples in this paper will be reported from ‘The User Group’ conference, “Profit from Data Integration: An industry update”, (NEC, Birmingham, Nov. 1998), to indicate how various organisations are now profiting from data integration in 3D object orientated modelling.
Benefits of data integration in building modelling: 3D object oriented professional collaboration
BENEFITS OF DATA INTEGRATION IN BUILDING MODELLING:
3D OBJECT ORIENTED PROFESSIONAL COLLABORATION

Introduction
This paper seeks to extend efforts towards encouraging our construction industry to become more efficient, competitive, responsive and accountable. Research shows a limited number of model companies and even small practices are benefiting from reorganisation and resourcing to centre the 3D object orientated CAD building model as the key building database to coordinate decisions by all those parties involved in the design decision making process. Together with co-members of the organising committee of ‘The User Group’ I have headhunted spokespersons for such exemplary organisations to bring together a series of presentations at their 14th Annual Conference. This was held at the NEC Birmingham on 27th November 1998. Members of ‘The User Group’ are dedicated to the use of object-orientated 3D CAAD design tools, particularly in the area of the integration of building data and building models and increasing interoperability. It evolved from the independent user group of the DEC- and Prime based RUCAPS/Autoprod building modelling software developed by the GMW Partnership in the 1970's, and expanded to include t2 Sonata in the 1980's and latterly Reflex, ArchiCAD and Architrion and is open to other like minded products and users. ‘The User Group’ functions combine application specific discussions with presentations on developments in the building industry as a whole and wider issues. This year’s conference theme was “Profit from Data Integration: an Industry Update”. Senior members of organisations were invited particularly to attend and be convinced by these progressive implementations of software centred organisation of building processes. Delegates were challenged: “Are you still using CAD systems only for producing 2D drawings and 3D perspectives? Come and see what has been achieved through intelligent solid modelling in the construction industry. The conference highlighted the use of Solid Modelling with object oriented data bases within the construction industry, displaying through presentation and demonstration the profitability already achieved from the use of integrated software solutions and charting the way forward.” Since the contributions were considered to be very significant and important to promote to the industry and there appears to be no tradition of published proceedings, it was agreed that I should report the substance of this conference to AVOCAAD to assist in the dissemination of developing good practice.

The areas offering opportunities for greatest ‘profit’
from the application of CAD to the building process, frequently identified during the presentations to ‘The User Group’ conference—“Profit from Data Integration” proved to fall in three main sections:

• Firstly, in early conceptual design: (If the client can understand the architects’ ideas at an early stage, it is possible to avoid persistence of misunderstandings progressing to the point, where redesign is too lengthy and costly and the client remains dissatisfied, or pays an outrageous figure).
• **Secondly**, if all groups involved in design and delivery of the building, are working on a single model, or an associated series of models, (to which all data is input and from which all data is output); it is possible to coordinate all the activities and decisions, to simulate and test reliably. This can achieve a more streamlined process, avoid conflicting information, ensure attainment of objective criteria, result in quality design which reflects the clients’ and designers’ ideals and save costs.

• **Thirdly**, integration of data on specified components within the 3D object orientated CAD model, leading to reliable takeoffs, can avoid the tremendous, costly, labour hold ups—(which could have been inevitable if poorly defined specifications had to be worked out on site).

‘The User Group’ intends to continue to press all members of the industry to **strive to push the boundaries** of research, teaching and experience forward, particularly in these notoriously destructive areas. My research seeks to identify, capture for explanation and publish good practice in these activities for explanation to students, academics and practitioners. This paper is planned to form part of this effort, by seeking to extract the key analytical, prognostic and prescriptive ideas and practice presented by the following contributors. The resumes in quotes are headed by presenters’ themes, names and associations and constitute extracts from these contributors’ full presentations to the conference. They are followed by my comment on each, in sequence, reviewing their contribution to the overall theme. I should point out that these comments are not those of the contributors. They are only my opinion, or my interpretation of parts of their fuller presentation and I welcome any challenges. For the full materials, readers should contact the contributors direct, (see footnotes), or access the WebSite—(http://user-group.biw.co.uk).

I have felt it useful to precede the said series of conference extracts with the following two sections, which I consider important to set the scene.

**Recent commentaries on this theme**

Following a long line of advisory reports, Egan, (1998) has suggested “enormous benefits are to be gained in terms of eliminating waste and rework . . . from using modern CAD technology to prototype buildings and rapidly exchanging information on design changes”. The UK Construction Minister, Nick Raynsford (regarding the role that technology has to play) stated (Gardner, 1998) “opportunities on offer include better client briefing and design management through 3D visualisation and company wide knowledge banks. More accurate costings, fewer errors and less litigation should follow, resulting in cheaper, high quality facilities that meet the client's need and ensure greater profits for construction companies”. Carney, IT Director at contractor Costain was also quoted by Gardner—“3D modelling and the use of a single model for the entire life of a project is streamlining the process. There are three key words in IT at the moment integrate, integrate and integrate. Software developers have responded by developing object orientated 3D CAD packages.” Also at Buro Happold, “individuals and design teams are able to harness the knowledge of their entire firm.” Mark Nellis is cited (Doyle, 1999) as saying, “If you computerise your drawings then you get a 20% cost saving and if you computerise your company processes, then you get efficiency gains of 1,000%. . . .The research and development budget of UK construction is absolutely tiny compared with other countries. Architects have a problem spending their own money but seem to spend other people’s like water!” CICA
(op. cit.) suggest that “expenditure on IT among architects averages 4-5% of practice turnover each year. . . ranging from 3% to 10% among the larger practices.”

Pleasing signs of progress include: (Fairs,1999) announced that the RIBA have commissioned a Future Studies Committee to “carry out ground breaking research aimed at quantifying the economic benefits of good architecture, particularly investigating whether it “produces clear commercial benefits for clients.” Fairs quotes RIBA’s Chris Palmer as citing good practice examples of “Evans & Shalev’s Tate Gallery, St Ives’ economic gains for the area”, while Bennetts Associates’ 1994 PowerGen Office HQ, Coventry had generated tangible benefits for the client”. Although the latter quotation is exemplarily pertinent to the discussion, I find it irresistible to wonder whether the implication is that it is unusual for architects to design benefits for the client!

**Government and industry: a brief critique of poor research base and reform**

A seesaw of buck passing seems to have persisted through recent history between the construction industry and government-led committees. I must attribute credit here to Crotty whose presentation at ‘The User Group’ conference, (reviewed here) laid a challenge that there had been a failure to pursue in-depth research and development into the underlying causes of problems in the UK construction industry, including the sequence of government committee reports. He does appear to be right in this analysis. Time and again committees set up by UK Government appear to rely mainly on their own expertise and not carrying out actual research into organisational processes and relationships. [Although the earlier report—(Emmerson, 1962) is described as a ‘Survey of Problems in the Construction Industry’]. (EDCB, 1967) remarked that “the Banwell committee’s recommendations and conclusions (Banwell, 1964) were not always specific or precise”. However they (EDCB), at least considered that in the complex relationships of the construction industry . . . involving clients of all kinds as well as contractors, operatives and professional men . . . no prescription can be right for all time for an industry in which the pattern of these relationships is bound to evolve.” however they considered that although the Ministry of Building and Public Works did not accept the Banwell report’s recommendation that they should confer with all the interests to achieve the “necessary coordination”, it is “up to the industry not the Government to create a body to do this.” It is interesting that (EDBC,1967) sought to reduce “the incidence of variations, which “ . . . would benefit . . . “the productivity of the industry”, yet they laid many problems of delays on the client’s “lack of decision or late decision”, “or changing his mind”, or not having “briefed the architect properly about his requirements” and even the contractor is charged that he “may not have asked for detailed information early enough”. This attitude of blaming every one else does not indicate a mature organisation capable of objectively conducting self appraisal and transformation! Again (EDBC, 1967) remarked, “One common characteristic of almost all variations is that there has been insufficient forethought before starting work on site.” Yet their solution seemed to be for the client to pay for his “misdemeanour” and for the builder to take responsibility for their own “explicit programmes for their work”. After over three decades, it is very disturbing to find the same problems being reiterated,
but this may not be surprising when we consider how little real onus has in
reality been placed on the industry to reform.
(Nicholson, 1998) suggested that (Latham, 1994) (a little more analytically),
“advocated a process-oriented team approach and a belief in the ethic of fair
trading” but failed to understand the “value of good design or the iterative
nature of the design process”. Since the Latham Report does not cite much
in the way of original research, it is hardly surprising! Latham did demand a 30%
improvement in productivity, yet is criticised by Egan, (1999), that it did not
establish any means to measure the improvements. At least Egan has said it
would “like to see” set in place a number of processes:
— the construction industry produce its own structure of objective performance
measures agreed with clients
— sharing of comparative performance data with clients and between
companies
— benchmark comparative success through the employment of company
“score cards” to measure “progress towards objectives and targets” for
predictability, cost, time and quality, based on performance indicators.
Again Egan (1999) seems to have followed the same track, i.e. a selection of
esteemed individuals were asked to meet and address a number of terms of
reference. The difference might be that their membership and expertise
included transformed construction organisations and in particular, people from
other industries which had already successfully transformed. They did draw on
research and did suggest specific areas for new research, including a £500m
programme for demonstration projects and a publicly accessible “Knowledge
Centre” based on the DETR Best Practice Programme data. So, the latest
round of investigations appears to recruit the companies of best practice, but
will this exclude opportunities for clients to challenge with evidence of the
need for further reform?

Why Modelling is Crucial to Industry Improvement—Ray Crotty,
C3Systems

The analysis
“Relationships in construction are as they are for a number of very good
reasons. They don’t arise simply because the industry is populated by short-
sighted egoists. They arise ultimately from two fundamental and currently
inescapable causes:
the lack of tools with which to communicate conceptual design ideas to lay
clients, and
the lack of tools with which to communicate the detailed design amongst the
professional team and between them and the construction team.
Modern buildings are enormously complex products and the project teams
required to construct them are correspondingly complex. These teams
generate huge volumes of highly complex information which must be
communicated accurately, completely and quickly to the large numbers of
participating firms.
It is the mismatch between this enormous communications problem and the
tools available to deal with it that gives rise to most of the apparently
dysfunctional culture and behaviours observed in the industry. The remarkable

1Ray Crotty Managing Director of C3Systems raycrotty@c3systems.co.uk
thing about construction is not that the industry performs badly. The truly remarkable thing is that, in the face of the complexity of its products and processes, it succeeds so often in producing buildings that delight its customers and genuinely enhance the environment.

The way forward
The attitudes and culture of the industry are those which are necessary to survive in the face of the mismatch between the complexity of the information we work with and the tools available to carry out this work effectively. To be more specific, they are the attributes necessary to cope with the confused, opaque manner in which project information is managed and communicated using the tools and techniques currently available. Perhaps the key point is that culture and attitudes are not, in themselves, causes; they are the effects of these more fundamental underlying problems. To focus on them, as Latham (1994) and Egan (1999) have done, while laudable, is not likely in itself to generate lasting change. The underlying causes must also be acknowledged, confronted and dealt with as effectively as possible.

3D Object based modelling systems provide the most promising means of overcoming these underlying problems. They should enable designers to produce 'What you see is what you get' conceptual designs and 'What you see is what you’ve got to build' detailed designs. Allied with pervasive broadband networks, models of this type will transform the operation and behaviour of the industry.

The Industry must stand by this vision and must become more active in the work necessary to realise it. This means contributing actively to the promulgation of classification systems like Uniclass and the Common Arrangement. It means persuading designers, particularly architects, to understand that they must take more responsibility for the overall information strategies of the projects on which they work. It also means persuading the industry’s educational institutions to incorporate information management as a core discipline in all of their programmes.”
Comment
Crotty presented a very clear analysis of the very complex and interrelated problems in the Construction Industry and the path to be followed to resolve them. Through his diagram above, he showed the interrelationship between technological development in practice and education and how important it is for research to investigate solutions to handle the complexities of the processes, to provide better implementation of full 3D modelling systems and to improve and develop tools particularly in the key areas of concept design and detailed design, including contract documents. The impact on the client is apparent. In his fuller conference presentation, he eminently explained why the stages identified are all executed "poorly, but could benefit from new technology, to ensure all parties are better informed of each other's ideas and so progress more effectively, speedily and with greater economy and quality. Those elements of the industry, who do not respond to the need for transformation, will perpetuate poor performance, (and poor quality achievers) and eventually will not be able to compete.
He pleaded with 'The User Group' to keep the "Focus on Geometry", the pressure on the International Alliance for Interoperability and charged everyone to "keep the faith". This drive should be extended to the wider national and international community hopefully, through this paper and the activities of AVOCAAD and other such proactive groups.
Crotty concluded by suggesting that the way forward for "’No Limits’ IT in Construction" lies in such technological developments as Concept Models for Visualisation, Detail Models as Engineering Prototypes, Pervasive Broadband Network services and Online Models and Repositories. Industry Actions should concentrate on improving the Classification Systems (e.g. International Association for Interoperability), the Behaviour of Networked Enterprises, Education and Research. Relevant Research and Development to inform training, education and learning are vital to reverse this downward spiral.
Crotty felt that UK government committee reports had not been based in deep investigative research into the structure and causes of failure of the building process. Rather, reference to these documents sees from Emmerson (1962) through to Egan, (1998), advisors and members of the professions being called together to share their expert opinions.
To summarise, Crotty’s main points were the complexity of the building teams, processes, information and products is not matched by an understanding from those involved, or effective tools. We should focus on the causes of the problems not on the effects. Information strategies based on 3D object based modelling provide the most promising means.

Sonata Special Interest Group address: Software Tools— Solid Modelling Future
Sonata Development, News and Future Developments—Nick Nisbet, Alan Jacobs, George Stevenson, Advanced Visual Technologies

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2 Nick Nisbet, Alan Jacobs, George Stevenson, Advanced Visual Technology Ltd, n.nisbet@biw.co.uk
“RUCAPS grew from being specifically developed for the Rhiyad University development to become a general purpose building modelling tool using plan, 2.5 and 3-D representations. Sonata introduced a broader and worldwide membership including many building services users and an increasing number of retailers. The recent inclusion of PC based products has broadened the membership yet further. Visual Technology, the developers of Sonata reported the steady interest in the product: major users such as HBG Kyle Stewart, Alfred McAlpine and Target, the Australian retail group had all invested in the installations. The program of annual updates to the application was continuing, with HTML and VRML support being delivered across the user base this year, and next March's release was previewed. Visual Technology also reported on their involvement with several major industry initiatives on ‘Partnering’, on industry standard component databases and the IAI. The continued vigorous growth of the retail sector meant that the company was attracting further investment to support continued growth. In the break-out session the users were able to report on their experiences and project workload and evaluate how the new releases would enhance their productivity.”

Comment
In private, Sonata users were privileged to hear of further developments and successful client applications.

ArchiCAD Special Interest Group addresses:

A working view: Property Objects—Steve Hendry and Richard Vertigan, Taylor Woodrow

An aim of Object Modelling
One of the ultimate aims of an 'Object' Model is to have the ability to be able to create any structure or set of components within the computer and have the ability to schedule off all the individual units and assigned data.

ArchiCAD
The Graphisoft Modelling Tool—ArchiCAD has the ability to assign data to objects using the Properties functionality. This feature allows user defined attributes to be held within any Object used in an ArchiCAD model or be attached to another Object as an Object in its own right. The information could be Specification data, part numbers, design information or costing information, in fact anything that can be written in a text file.

Practical uses: Gatehouse
Taylor Woodrow (TW) have used the Properties functionality of ArchiCAD on previous projects as demonstrated at the User Group Conference, with the GateHouse project. This project was modelled to a higher level of detail than is usually carried out on most projects. It even included the addition of objects to represent reinforcing bars in the foundations of the structure. This allowed the scheduling (Bill of Quantities) to be extracted to a much greater detail than usual. However the benefit of using Property Objects is that the model doesn’t have to be modelled to a higher detail level. The properties required for

3 Steve Hendry and Richard Vertigan, Taylor Woodrow Construction Ltd. Europe (Building) Division, steve.hendry@taywood.co.uk
Benefits of Data Integration in Building Modelling: 3D Object Oriented Professional Collaboration

Scheduling could be held in their own object and simply applied to a structural element.

**Gatwick Airport**

TW are currently working with BAA to extend the South Terminal departures lounge. To aid with the design and site management a 3D Computer Model is being developed using various tools including ArchiCAD version 6.0. The design is intended to be based on Component Design. This means that the manufacturers’ standard components are used wherever possible in the design of the structure, i.e. The design is more manufacturer driven than usual. Non traditional methods of incorporating the mechanical and electrical services within the structural elements are also being developed.

The ability to include all relevant information within the model should prove to be a great benefit. It is intended that the data contained within the model will be used to coordinate all of the design disciplines. The model already provides the ability to schedule off the steelwork members with their correct properties. This allows easier checking of the consultant’s design and the fabricators’ information. As the model develops the continuity between the various disciplines can be checked and any extra information assigned to elements could be a benefit later on, e.g. suppliers’ details and part numbers assigned to light fittings can be of benefit when constructing the project and on completion if used as a Facilities Management tool.

**Future**

It is already possible to create an Object Model with assigned properties, it is however quite an ordeal to input and retrieve the information. It is hoped that in the future the tools used will develop to make the process easier and quicker.

**Comment**

Taylor Woodrow are to be congratulated on charting the implementation of the Component Data Base for ArchiCAD. Though limited data attachment has been possible with previous versions of this object based CAAD program, Version 6 has wide ranging potential. The detailed work process for Taylor Woodrow, involved creating text files from Standard Method Measurement books’ takeoffs to act as Component Details attributed to objects in the model. However once Industry standard descriptions are made available as immediately compatible files, the process will be simplified. (Though each organisation will need to establish their own standards and records for details).

Taylor Woodrow illustrate very clearly a function of the 3D Object Model—to coordinate data for all disciplines involved in the design and construction and specifically referring to consultancy, fabricating, supply and Facilities Management with reference to the example of steelwork scheduling.

**The Future of ArchiCAD—Andras Haidekker, Graphisoft, UK**

How do ArchiCAD developers think about the future? The major driving force is a mission critical application responding to dependency of the team on the need for projects to have reliable functionality for the whole efficiency of

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4 Andras Haidekker, Graphisoft UK  
ahaidekker@graphisoft.co.uk
design. If the data is integrated we do have profit. Interoperability is essential. The system is programmed to be: powerful, easy to use, reliable, stable, appealing, high tech. and affordable. We would like to serve the industry for the whole process of virtual building, in its whole life cycle. ArchiCAD began in 1984.

The drivers for development directions are:
• One of our biggest assets is that we know what people want, from our database of wishes received from the users (over 50,000), sorted by keywords.
• We consider which new technologies to build into ArchiCAD. (Over three years ago we had the foresight to build QT VR into our software).
• We have our own ideas for several new directions.

We are removing more and more geometric constraints, taking up real opportunities from internet technologies, giving importance to database links, introducing much more graphical user definition in editing parametric objects, planning much more freedom in architectural modelling and more solid modelling. ArchiCAD also now has an essential role in Product Design and Mechanical Engineering, which is even more critical and complex than architecture.

Comment
Graphisoft's concern about users' opinions is historic, dynamic and probably explains their popularity.

Partnership API products—Istvan Janasa, architect, Graphisoft, Budapest

New products in various stages of marketing readiness were presented. Some are loaded from ArchiCAD and some use output from ArchiCAD. API—Application Programming Interface was developed by Graphisoft for 3rd party developers to use in association with ArchiCAD. All kinds of data can be seamlessly exported from and imported back to ArchiCAD. The ArchiCAD Presenter takes over from Playback. It is a multimedia editor tool with sound, buttons, etc. Plans can allow plotting of cameras used A media folder can be created. A comprehensive score template is used. HTML export features are planned. A new piping tool is in the Beta stage, developed by a German company. It takes exported data from ArchiCAD. The data can be processed, in typical piping controls, but including detailed joints and lists. Results can be imported back into ArchiCAD. The RoofMaker is also in the Beta phase. It simplifies the creation of complex roof structures in detail. It acts according to the particular structural component, such as rafters, trimmers, perlins, studs, posts, collar beams, etc. and it is intelligent in situations such as the edge of roof lights, or even a curved eaves line. A new API, more sophisticated Stairmaker is also on the way. It takes exported data from ArchiCAD. The data can be processed, in typical piping controls, but including detailed joints and lists. Results can be imported back into ArchiCAD. The RoofMaker is also in the Beta phase. It simplifies the creation of complex roof structures in detail. It acts according to the particular structural component, such as rafters, trimmers, perlins, studs, posts, collar beams, etc. and it is intelligent in situations such as the edge of roof lights, or even a curved eaves line. A new API, more sophisticated Stairmaker is also on the way. The interface routines of c++ tool API is ready and working. ArchiCAD functions with API as an architectural engine.

Gary Lawes of ArtSystems, Ltd. followed and explained how the new distribution system works in the UK and the support they provide.

Comment
With these new developments added to the extended performance of the existing version 6 of ArchiCAD, which allow interoperability, component
database integration and fully 3D modelling on the fly, ArchiCAD has extended application for the construction industry based on its original object oriented structure.

**New Drive Technologies: Backup Media and Drives—Mark Littlechild, Pioneer Uk Ltd**

There follow some notes from the presentation: “What is DVD? New Discs and New Hardware. DVD - Digital Versatile Disc. Very High Capacity Removable Storage Medium. Standardised by all major electronic manufacturers. Backward compatibility with CD. Will eventually replace CD-ROM drives, CD Players and Video Recorders. DVD Disc is physically similar to CD. CD and DVD discs are both 120mm diameter. CD is one disc of 1.2mm thickness.

DVD is two discs of 0.6mm thickness bonded together. DVD Capacities: DVD-ROM Discs: Very High Capacity ‘CD-ROM’ discs, 4.7GB disc = 7 CD-ROM discs, 8.5GB disc = 13 CD-ROM discs, 9.4GB disc = 14 CD-ROM discs, 17GB disc = 26 CD-ROM discs. More choice and flexibility for software developers

**DVD Categories:**

- **DVD - Video, DVD - ROM, DVD - R, DVD - RW, DVD + RW, DVD - RAM**
- **DVD Video:** Very High Quality Digital Video & Audio. Up to 133 Mins of “Movie”. 8 Sound Tracks, Different Languages. Dolby Digital Surround Sound.

Available Now

- **DVD - ROM:** Read only Memory. DVD Discs are pressed at factory. 4.7 GB, 8.5 GB, 9.4 GB, 17GB
- **DVD - R:** Recordable Write - Once DVD - Safe data, 3.95 GB Capacity, More than 6 Times CD-R Capacity, Compatible with DVD - ROM, Compatible with existing DVD hardware

Available now

- **Rewritable DVD:** No standard yet set. Confusion over competing formats
- **Pioneer DVD - RW:** is the only format that can be read by other manufacturers drives

What are the Benefits to you? Huge Data storage capacity

Ability to store computer data as well as video and audio. You can still use your computer CD’s on DVD ROM Players.

Where do Pioneer Fit in? Pioneer is founding member of the DVD consortium.

Pioneer is chairman of the DVD working group on DVD - R, DVD - RW.

The New DVD Autochanger: DVD - ROM Version. 850 GB Capacity DVD-ROM. 395 GB Capacity DVD-R. It can read CD-ROM, CD-R. More data per disc. Investment proof - Formats have been set”.

**Comment**

The two big differences between existing CD technology and DVD are the capacity and the data transfer rate. It is this last difference which matters for showing video and storing large computer data sets. Even though most new CD-ROM drives are fast, there are still many in use which are not fast enough for video.

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7 Mark Littlechild of Pioneer Electronics UK contact: Andrew E Wilson, AndrewEWilson@compuserve.com 01753 789735
The other advantage of DVD is that there is a standard format which can be put on to the disc which ensures that everyone will be able to play the video, and that is the DVD-Video format. This involves preparing your digitised video in the correct form, and ensuring that the file names and other details are special to DVD-Video. You will then be sure that the DVD can be played in a DVD video player, or on a properly equipped computer.

The capacity and capability of DVD is of particular interest to the design community with its tremendous increase in capacity over CD. It is reassuring to know that these formats are already available so soon.

It appears that Pioneer, the “pioneers” of the Laser disk, have again “pioneered” these media and drives.

“Data Integration: Integrated Appraisal of Environmental and Cost Performance—Dr Don McLean, Integrated Environmental Solutions”

The audience were invited to play a simple interactive game. Pilot McLean of the inaugural flight of McLean Airlines, addressing the passengers (audience) asked them to indicate as soon as they felt uncomfortable, as he explained that before building this plane, they had taken a look around Birmingham Airport, sketched a few planes, made physical models with a couple of wings, thrown them in the air for testing, backed up with a few hand calculations and were now fairly confident it would get into the air, but if there were any wobbles, they would do last minute bits to it! He explained the building parallel, where the disintegrated members of the design team are without any real understanding of how the building will operate until it is actually built and we ask people to use it. The team tends to concentrate on building production, rather than building performance, without any real understanding of how the building will operate until it is actually built. Clearly this is inefficient and costly. **IES are trying to give the design team the information that allows them to assess how the building will perform prior to being built.**

By comparison he panned through “the IES <Virtual Environment> a unique system that extends the concept of Virtual Reality for building designers. Instead of only visualising the 3D space the designer can investigate how the building will perform in terms of daylight and electric light, occupant comfort, low energy design, air quality, sustainability, health and safety, and capital and running costs. To be able to perform these assessments computer software is required that will simulate the building. This is equivalent to building a physical model of the building within the computer and testing how the building will operate. The IES <Virtual Environment> consists of simulation software, which provides invaluable information that enables architects and engineers to have much greater insight into how the building will actually perform after it has been built. Consequently, designers can optimise their designs, thereby improving the quality of the built environment for the benefits of society in terms of better buildings using less of Earth’s resources. Many experts recognise that simulation software will have a greater impact on the design process than CAD. Already building simulation technology is being used on an increasing number of projects.

The <Virtual Environment> system has been proven to not only enhance the design process but also result in significant capital and running cost savings.

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8 Dr Don MacLean, Integrated Environmental Solutions Ltd, Glasgow
drdon@globalnet.co.uk, drdon@ies4d.co.uk http://www.mies4d.com
However, in the longer term, the use of simulation technology will result in a shift of emphasis in the design process. The design process will be no longer centred on CAD, as more effort will be taken at the early stages of the design process allowing design teams to make more effective design decisions. With the proliferation of simulation technology it is possible to achieve the 30% savings in building costs identified in the Latham and Egan reports. The <Virtual Environment> is available now and is already helping architects and engineers provide us with a better-built environment.

The <Virtual Environment> operates from a base model of the building, called the Integrated Data Model or (IDM), created by the IES ModelBuilder. The ModelBuilder allows users to create models of the building that can be used with and without CAD data allowing the designer control of the design process.

There are five distinct categories or product ranges, other than the model building tools, as follows:

**The DEFT Product Range.** Design feasibility tools built around a Value Engineering tool called IDEAL.

DEFT stands for Design Evaluation and Feasibility Tools. The Facet M&E Calculation Product Range is a set of productivity design tools for Mechanical and Electrical design. The VE-Draft Product Range is a range of M&E drafting tools for building designers. The 4D Building Simulation Product Range is a unique set of design based simulation products. These products are easy to learn for in-house use. The 4D+ Product Range are physics based, detailed simulation tools for use by committed organisations.

![Figure 2: The 5 product ranges. © ies.](image1.png)

![Figure 3: Model Builder. © ies.](image2.png)

**ModelBuilder**

The major advantage of an Integrated Data Model (IDM) is the substantial reduction in time and effort required compared with using the many different products which each require a different data model. ModelBuilder is key to the IDM as the ModelBuilder is a suite of integrated software tools which provide an interface for the creation and subsequent modification of the IDM for the IES <Virtual Environment>.

The starting point for the IDM is a 3D geometry model of the building. This can be created from one or more sources: CAD data available via data converters; or using the IES 3D geometry creation and manipulation software called ModelIT. Attributes are automatically assigned to the 3D geometry of the model to complete the IDM in ModelIT. The ModelBuilder is easy to learn and
use, and allows the user to build models rapidly, with good data checking facilities.

1. **The DEFT Product Range** is aimed at providing analyses of the building at the earliest stages of the design process. The tools within DEFT are unique and offer the designer the ability to perform Value Engineering assessments at any stage of the design process. However, this facility has maximum impact at the early stages of design. Organisations can compare building options based upon variables such as capital cost and thermal performance. The basic concept associated with DEFT is that key performance indices are calculated. These indices can be weighted to enable the effects of different building design options to be compared more effectively allowing the people involved in decision making to do so based upon accurate information.

![Image of DEFT software interface](image_url)

Figure 4: Analysis of any building design option based on weighted performance indicators at earliest stages. © ies.

2. **The 4D Building Simulation Product Range** consists of building simulation software that can be used to conduct performance assessment analyses to provide an understanding of how a new, or refurbished, building will operate prior to being built in terms of air flow, energy usage, occupant comfort, lighting, and so on. Substantial capital and running cost savings can be achieved with the 4D tools either at the design stage or as part of Energy and Facilities Management. The 4D performance assessment tools operate on the IDM of the building, created by ModelBuilder: thereby maximising the use of the time spent initially creating the model of the building. The 4D range consists of modules that are easy to learn how to run and use. This is an important distinction when compared to the 4D+ products.
3. The 4D+ product range is a complementary suite of building simulation products to the 4D Product Range. The major difference between 4D and 4D+ is that the 4D+ product range is more detailed, only to be used by committed organisations. The 4D+ products tend to require more training and more experience to get the best results.

4. The Facet range of design calculation software is a powerful set of building-services applications for use by Mechanical and Electrical engineers. With Facet software, you will be able to calculate heat losses and heat gains; pipe and duct sizes; lighting requirements and levels; cable sizes; noise levels and more – with accuracy and ease. The Facet products are simple to use, and significantly increase design productivity and efficiency. The Facet design calculation tools, which have been developed by engineers for use by engineers, are widely recognised as the most technically credible products of their type on the market. The technical excellence and benefits of the products are well recognised and appreciated by Facet users.

5. The VE-Draft product range is a powerful set of CAD drafting tools, which help the designer achieve substantial productivity gains when using AutoCAD and MicroStation. Designers working within a CAD system can call upon the Facet calculation tools for heat loss and heat gain calculations; pipe, duct and cable sizing; and lighting-design and analysis”.

Comment
The world’s first “Environmental Reality” system allows building designers, owners and occupiers to simulate the performance of a proposed new or refurbished building. The company is called “ies4d” because, for the first time, it adds a new dimension to existing CAD systems by considering time as a parameter. <Virtual Environment> can achieve impressive capital and running cost savings. Capital costs of £300,000 were, for example, saved on a recent project. Significant environmental benefits in the form of reduced energy consumption and subsequent reduced greenhouse gas emissions have frequently been achieved using the software which performs thermal simulations of buildings and plant, solar shading analysis, visual impact assessment, airflow and lighting simulations, as well as tariff analyses and selection. In addition, <Virtual Environment> can help solve many of the “Sick
Building" issues such as: minimising the extent of summertime overheating; the use of natural ventilation against air conditioning; the optimisation of occupant comfort; the effect of local air regimes and quality on occupant health and performance.

McLean's presentation of the 'IES Virtual Environment' appeared to resolve so many of the dilemmas of design today, bringing tremendous flexibility, yet potential for accurate targeting and resolution of: the client's needs, economy and the many other criteria to be tested. Examples of projects where the software described above has been successfully applied are myriad and impressive. IES has worked on many high profile projects such as the BlueWater Shopping Mall (the largest in Europe), The Royal Albert Hall and The Millennium Dome, regarding which the construction minister, Nick Raynsford stated (Gardner, 1998): "At the Millenium Dome, the clients, consultants and contractors have been linked together allowing easy exchange of documentation". Whilst not all the software is unique, the interactive total bundle probably is and can be operated in association with known CAD products. This software was developed by Don McLean and the Integrated Environmental Services team over 20 years, initially on Unix predominantly to provide a design consultancy support service, but they are now migrating their software to pc to make it available for sale. One client reported back when their building was completed to say it was "performing exactly the way you said it would"—a small indication of their great success.

The software is impressively based in the rationale of each process, thought through relevantly to embrace important criteria, but not wasting time in irrelevance. For instance, only the simple break point of relevance is calculated, to show critical levels, but when testing for evacuation—simulation (e.g. from a football stadium) allocates in detail, behaviour by type of person and how they will move, even twisting into available spaces. High costs in time and possible failure of the design to meet the client's criteria, [whilst being in a rather blinkered state during debate with the design team at the conceptual design stage], can be saved through careful use of this software. IDEAL within DEFT enables Life Cycle Analyses to understand what the client wants and what people in the team are going to do. Important design needs can be fed in at an early stage and tested out. Alternative parameters and criteria can provide a clear technical and marketing differential of what you are doing in different options giving out different performance.

The simulations can be seen to be tremendously useful in facilitating informed, reliable decisions. The technical data are shown as 3D visualisations, making greater sense to all members of the design decision making team from lay client to the most technical and allowing them to "start to mould the clay." McLean made it clear that opportunities for successful realisation of designs, now improve performance at all stages including giving precise parameters for all components in the building process, so avoiding the traditions of oversizing for safety.

Mr Doug Wilkie, of IES has said, "We believe that existing CAD users will prove a receptive market for <Virtual Environment> because it will run on their existing hardware and it will offer them a real competitive edge when dealing with their clients who increasingly seek better solutions and proof of performance."
The presentation concentrated on the use of ArchiCAD on a £16m refurbishment project. The Adams building is a Grade 2* listed building in the heart of Nottingham. Built around 1855 with gross floor area of 11000m2 approx. It was originally used in lace manufacture. In later years it was in multiple occupancy and was suffering from a lack of maintenance. The refurbishment involved the change of use to Further Education. It was funded from various sources including the Heritage Lottery Fund and Private Finance Initiative. CAD data for the project came from several sources, e.g. survey, structural engineers, service engineers and several specialist sub contractors. This was from various CAD programs. DXF was used generally for transfer. There were problems with this, the result of which was that a single project model was never assembled. This did lead to some coordination problems on site but none which were insurmountable. The important thing was that the architect's plans were used as the base for all other disciplines. Output from ArchiCAD was used for many varied uses ranging from working drawings to 3D rendered drawings of specific areas and stylised plans for signs. The latter were important in the submissions to English Heritage for LBCs & funding. The ArchiCAD model was also used for quantity takeoffs for floor finishes, etc. and for Further Education Funding Council area use analysis. Overall the project was completed on time within budget and has started the urban regeneration process in an important part of the city. It would have been very difficult to have completed it on time using traditional drawing methods. Whilst there were some problems with the use of different CAD packages they were overcome relatively easily. ArchiCAD proved itself to be a very flexible program which easily coped with the demands of the project. The project is deemed to be a success by the users and as a practice we are delighted to have contributed to it”.

Comment
Richard Thorpe illustrated the whole process in great detail in his live presentation, demonstrating how use of 3D CAAD object modelling brought to this Nottingham Lace Market project: flexibility, team coordination facilities, Client/User’s space planning opportunities, greater speed in executing the project, ease of production of outputs for working drawings, quantities takeoffs and promotional information. The data exchange between CAAD programs was not quite seamless at the time, though doubtless, he would now not have encountered these difficulties through use of DWG with the new version developments.

“Integration Using Component Based Design: Contractors Case Study—David Pyle, Taylor Woodrow and Frank McLeod, HJT Consulting Engineers”

9 Richard Thorpe, Crampin Pring McArtney, nottingham@ cpm-architects.com
10 David Pyle, Taylor Woodrow Construction Ltd. Europe (Building Division), david.pyle@taywood.co.uk
The context of our presentation on component based design, is to give you an insight into the project, which we are working on with BAA Gatwick. Our purpose is really to try to give you a vision of what we need as end users, or effectively your clients. ‘Rethinking Construction: The Report of the Construction Task Force’ (Egan, 1998)’s influence on the industry and how we have got to align with his thinking, has really set us as suppliers, five drivers and four processes that we have to try to look at and try to implement improvement, project implementation, production of components and integrate the process & the team:

Drivers
• Committed Leadership
• A focus on the customer
• Integrate the process & the team
• Quality driven agenda
• Commitment to people

Processes
• Product development
• Project implementation
• Partnering the supply chain

We consider we need a pull not push approach to the construction industry. We have created an environment where we can integrate the team. We had to define the Component Based Design process—“The process of developing a design based upon the maximum usage of standard components, placed in the context of the project so as deliver the greatest benefit. Designing in a modular manner set the scene for modular construction”.

**Production of components.**
We are taking a first step in production of components. By designing in a modular manner and using available components, we have been able to
achieve significant improvements now, but, more important we will set the scene for the modular designer. That then leads on to prefabrication. The problems you’ve got on the project are about getting the rigors into it. It’s an evolutionary process. It is about us aligning ourselves with Utopia, but getting rigor into every step in the project of component based design. Designers are delivering information to the construction industry. Quantity Surveyors have to become cost stylists as part of the design process. The design starts with understanding the system and components. Define the products at BAA e.g. baggage handling, etc.. Define the system, e.g. Chilling. And we want some data on the components—Time, cost, etc.. What fixes the component? What would allow us to run off these components? Doing that you get the component’s Fixity. Last Planner says “You have to make the component” You need those x things before you can make it. Then we look at interrelationships,[Fig.10]. Process maps fill the wall. Design team meetings are about full intellectual understanding of how the building works. We can source the whole project on day 1 and choose the best experts to place components in the building. We have the right PEOPLE, PARTS AND PROCESSES. [See Fig.9] We will tell the architects “You are not allowed to build unless you fully understand the building.” We will whack Egan’s 30%. The model is a database—a massive repository of information. A real time coordinator can say ‘excuse me you have just clashed with something else”. We want small handleable packets of data to work on separately, for easy handling. We want the model coordinated early for components with very simple diagrams as output, e.g. put tab A into slot B. What are the tools? (Fig. 9) The final thing we need is to facilitate the funds to create the tools. It is not going to stifle design of beautiful buildings. (Figures 6 to 12 © D. Pyle and Frank McLeod).

Comment
This exemplary case study indicates the benefits of understanding the process, breaking the process down into deliverable components to design a system to input and output simply and reliably. Working through the whole process backwards they want the model to come out into component manufacturing.

Sharing of Data for Design and Build Contracts—Philip Palmer
HBGConstruction

The HBG Construction and Intranet Drawing Issue System
The HBG Construction Intranet Issue System utilises Internet technology to make CAD drawing data available to members of the design and construction team. The objective of the system was to provide a ëpullí rather than a ëpushí system where drawings are made available in a central location via a Web server.

The system involves various cgi and perl scripts to post forms, etc. to the Intranet server. The Intranet server comprises of a Silicon Graphics Webforce server running from one of our many Sonata CAD workstations. The system firstly registers drawings via certain question and answer forms and is structured to take account of all design discipline drawings along with

11 Phil Palmer, CAD Developments Manager, HBG Construction, ppalmer@hbgc.co.uk
any sub-contractor drawings we may have to issue on their behalf. Any user with the necessary permissions can then issue the drawings they require from the register and also choose who to issue them to via certain scripted forms. The system will then produce a static web page of the issue sheet along with the list of drawings they have issued. Hyperlinks are added to the drawings so that the users can then simply click on the hyperlink which will then launch a suitable viewer to view the file on the web server.

Various file options were looked at for publishing to the web and due to the lack of file type exports from Sonata, (our main CAD system), we decided to publish direct HPGL plot files which we could also easily obtain from our sub-contractors, etc.. A cheap plot file viewer was then installed as an application on the design team’s PCs which gave them the ability to view, print areas to local A3 and A4 printers or plot the entire drawing to a large format plotter. For site purposes we provided the site with a suitable plotter, so they could then plot the drawing out at full size if it was deemed necessary and then any additional prints could be sourced from a local printer close to the site.

The system was successfully used on two main contracts to the value of £80m at Thames Valley Park in Reading for two of our clients Oracle and Argent Development Consortium.

**Future improvements, database development and inclusion of client and consultant access**

The system was initially tried as a pilot and was very successful in its use and saved much time in providing the design team with instant access to drawings along with a direct link to site rather than waiting for drawings to be posted. The future intention is to make our Intranet area accessible to the client and his consultant team as at present it is an in-house system. Certain areas are being looked at including network security for dial-up networking, file format for publishing, viewer technologies and current line speeds from remote sites. The future intention is to further develop the system to include a database behind the system to give us more flexibility in what we can achieve and to make the system available to all members of the project and provide a secure Extranet based system.

**Comment**

Phil Palmer shows here, how HBG Construction’s CAD Organisational and Profitability Strategy for data integration within a multi-discipline Design and Build environment has provided data to the project teams on an Intranet Server for distribution. Software and hardware have been designed to introduce new technology to people’s desks and on site, (in an excellent Intranet based, ease of use implementation), in order to coordinate and distribute drawings between the design team, subcontractors and the site construction team, so bringing great cost savings. It will be interesting to compare the delivery of their plans to provide access for the client and consultancy team, implemented through an Extranet with the early implementations of client control through CAAD by Sasada, (1994, 1995).
Data Integration and the Building User— Rachel Perrin, Scottish Provident

“Rachel Perrin is a qualified Interior Designer working for Scottish Provident UK. She and her colleague Nadia Zokhrouf from the Space Planning team in the Premises Department are supporting Facilities Management, strategic allocation of space, ascertaining departmental working relationships, procurement of suitable accommodation and liaison with architects, consultant engineers and other professionals, whilst responding to constantly changing business requirements.

Their task indicates a need for integration of a variety of data and functions, namely “The integration of the client’s requirements with building facilities and services to accommodate staff in efficient groupings and produce the best working environment, while paying due heed to Health and Safety and other legislation. Cost and feasibility are also taken into account.”

The Scottish Provident’s premises complex in Edinburgh comprises an early 1960’s modernist glass and granite, grade “B” building and an admix of Georgian and Victorian facades. A total refurbishment to modern deep plan offices had left only the facades as original”.

Rachel Perrin and Nadia Zokhrouf worked closely with the contracted architects on relocation and redesign of a centrally placed staff restaurant and meeting place to be easily accessed from all new areas of the administrative centre. The team promoted Fletchers Joseph Architects’ ideas through ArchiCAD visualisations. The team’s selection of materials and textures produced an exceptionally accurate indication of how the design would look. Rachel showed a number of paired examples of photorenders with photographs of the materialised scheme, which indicated this. They did also consider that the ArchiCAD facilities for design, space planning, walkthrough and 3D were advantageous “when demonstrating layout concepts to clients uncomfortable with architectural drawings”.

Comment

This project demonstrated integration of the processes fully involving the roles of contract architects, interior designers, facilities managers, space planners, engineers, client user and occupant groups.

Model Data Integration in the UK Construction Industry—Dr Robert Amor, BRE/CCIT

“This presentation looked at the grand vision of Integration which is a repository of all project information, lasting the whole life of a building or project, including all relevant views for the different industry groups, available to all in the project, and always consistent and up-to-date. This view is clearly decades from a reality, but many inroads have been made towards achieving this goal. Work on this area over the last two decades has highlighted several lessons, including: the fact that integrated systems have to be tightly linked with all processes in a project; that documentation aspects of a project have to be tightly coupled with the data aspects; that legality aspects need to be considered in the development and use of an integrated system.
A survey of the history of integration work shows that many of the concepts pre-date computerisation, including the work (continuing) on classification systems. The 1960's saw the development of simulation tools and even VR prototypes which highlighted the need for integration across these systems. The 1970's saw the development of CAD as the integrator and DXF and IGES definitions which only partially tackle the integration problem. The 1980's saw the development of ISO-STEP models for construction, but with little success. The 1990's saw the industry-led development of IAI-IFCs for standardisation, as an underpinning development towards integration. A survey of the work being undertaken in the UK shows two distinct camps. In the research and government supported development there have been many prototypes in limited domains and for limited life-cycles. These have tended not to be scaleable to commercial systems. In the commercial world there are no systems for sale, but some in-house development to provide consultancy edge. These systems tend towards project specific, with a small number of tools, bespoke communication regimes, and bespoke data models. Analysing the current situation indicates that in the next few years integrated systems of a limited scope are likely to become more common throughout the industry. However, the ultimate goal is not on the immediate horizon”.

Comment
Amor summarises clearly for us how the notion of data transfer and integration predated much of UK CAD developments and has continued into the era of CAAD implementation in the Construction Industry in the UK, but in a very incomplete manner. He considers that, “In the commercial world there are no systems for sale” and that “the ultimate goal is not on the immediate horizon”, yet he may have been pleasantly surprised by Don McLean's announcement that Integrated Environmental Systems' suite of software has now moved from their consultancy use, into the marketplace.

“CAD Integration in Scandinavia Compared to the UK—Prof. Rob Howard, Technical University of Denmark 14
This presentation provided a comparison of progress in Scandinavia compared with the UK and covered background to the survey data and research programmes in Scandinavia, surveys with Sweden and Finland which have major IT development, cooperation with other Scandinavians via Extended Nordic Collaboration, initiative, programmes, integration - an early goal now being realised - benefits expected in Denmark, standards - summary of progress with CAD layers, STEP and IFCs, Scandinavia - levels of CAD use, types of data structures, communications and the future - how integration evolves, changes in construction and when is the pay off. The full presentation can be obtained from the author, however a resume only is provided here.
“The survey of Information Technology use in architects, engineers, contractors, building managers, trades people and material suppliers, was started by the Building Economics Department at KTH as part of the Swedish IT Bygg project. The same questions were asked in Finland as part of their national IT project, TEKES, and its VERA building initiative. In Denmark there is no similar national IT project but, to maintain the idea of an IT Bygg centre and identify how it could promote use of IT, it was felt important to update

14 Professor Rob Howard, Graphical Communications, Technical University of Denmark, rh@gk.dtu.dk www.ifp.dtu.dk/~it/itprh/html
information last collected by Lars Schiott Sorensen of DTU (Sorenson, 1995). Norway was not included, but some comparable data for the UK was supplied by Barbour Index on their users’ access to computers and the Internet (Barbour Compendium, 1998). [See Fig. 13]

**Integration**

The need for integration was identified in the 1970s. The single, common database is difficult to build. It is more successful to link a few applications. Modelling offers objects for integration. Partnering on projects allows data sharing. Research exists on IT in Danish housing consortia. The Nordic IAI is active in the development of IFCs.

![International Comparison of IT Barometer Results](image)

**Effects of IT on productivity**

The message from the Danish survey on the greatest increase in productivity is very clear - administration and design are the two tasks on which the greatest number of firms were enhancing their performance, and this is reflected in Sweden only with even more firms claiming greater productivity. Management fields, such as project management and, particularly, site management, showed little change in most firms. This may be because management applications require greater change in peoples’ attitudes and methods of working and do not just involve automating the production of similar documents to the ones produced previously.

Indications of growth in Object oriented models is apparent in Fig. 15. In Denmark, strangely only 4% declare use of Object oriented models, yet 8% say they use 2-3D Objects and 265 reference files and databases. Similarly, in Sweden, 11% say they use Object oriented models, yet 24% -2-3D Objects and 22% Reference files and databases. It would seem there may be a misunderstanding of the terminology.

![Productivity from IT](image)
Plans for investment in IT in Denmark are also quite clear, although a lower level of investment is expected in the next two years than has been made in the last two. The leading areas in which Danish companies intend to invest, as reported by percentage of respondents, were: CAD (58%), accounting systems (47%) and Internet/Web (46%). Document handling has the highest priority in Sweden (70%), where the CAD market is more saturated, but it is also high in Denmark (37%). Product models, EDI and Virtual Reality have very low priority in both countries, probably because they are new technologies and have yet to show real benefits.

The Future
Products are superseded but integration evolves. Gradual integration of successful applications e.g. NBS, Spec Manager, Annotation Manager, Barbour. Integration needs changes in construction e.g. Partnering, Design & Build, Build Own & Operate. Danish research on Housing Consortia with different levels of IT, measure efficiency of communication. So, when is the payoff? The benefits of IT are improving all the time but fees are lower. IT now taken for granted. 30% savings were nearly reached in recession. If the same team worked on several projects and conformed to relevant standards and there were some useful building objects:

The technology exists now to support real integration, if we can organise ourselves.
Comments
If use of databases and reference files is used as an indicator of data integration processes in Denmark and Sweden then a quarter are active in this way. However a very small % admit to using object oriented models.

Chairman’s Summary—Michael Hohmann, LMH Design
The keynote address given by Ray Crotty, MD of C3 Systems Ltd, provided an overview of the construction procurement system as is, and as it should be following the Egan report, which to implement practically, requires the use of virtual building models and the existence of practitioners bridging disciplines, platforms and systems in a forum such as the User Group. Advanced Visual Technology Ltd, the developers of Sonata, reported the steady interest and investment in installations by major users such as HBG/Kyle Stewart, Alfred McAlpine and Target, the Australian retail group. They also reported on their involvement with several major industry initiatives on Partnering, on industry standard component databases and the IAI. Graphisoft, the developers of ArchiCAD, announced that Version 6 will support IAI IFC 1.5 input/output extensions by mid-1999, a series API associate and easy to use add ons, the new software development kit for use by third-party developers of plug-ins and the debut of "SalesCAD" in Austria for the BauMax-x chain of building materials suppliers.

Conclusions
By the end of the conference the solutions and ‘profits’ from Data Integration best practice were emerging. Howards’ Fig.14 shows exemplary productivity in Denmark. Crotty’s diagram gave a clear analysis of the dysfunctional aspects to be researched and resolved. Amor felt we have a long way to go. A number of the contributors to The User Group conference made common identifications of problems soluble through 3D object orientated building modelling. The first commonly defined problem, focused on the accumulating failures, which escalate, when early conceptual sketch designing does not make key decisions explicit enough to the client, who remains bemused about the architect’s dialogue until nearer the realisation of the project, when the designed features become more apparent. Typically at this late stage the client is able to articulate what is required against this more familiar visualised definition. Costly failures are however are incurred at this late stage, in either dissatisfaction, disfunction or uncosted redesign. Fortunately, McLean explained how the ‘ies<Virtual Environment>’ software addresses these problems, by setting a framework for the professional/client team to clarify important design criteria, which establish objectives with performance indicators, which provide a stark challenge. Some of these processes can be achieved to a limited but useful degree, by a mix of using existing software in a more diagrammatic conceptual manner [block model, analytical approach], together with agreed overt objectives and performance indicators. This occurs early in the process and together with the new electronic sketch designing tools, should bring the designers’ conceptualisations into vision for the clients’ more informed response, at this early conceptual stage, and clarify and coordinate the whole professional team’s thinking, moving towards Crotty’s ideal of “What you see is what you get”.

A second major and again costly problem is that of the absence of a common language and centre for building dialogue, where all the professionals involved
may relate, test and if necessary modify their input. The present typical mode of working sees abortive, traditional testing, or many separated electronic modelling activities, which are not really collaborative, coordinated, or common and in many ways unnecessarily repetitive, costly and slow to identify features clashing with the design team objectives and professional and industry standards. Again the contributors (and notably McLean) showed that new tools and programs are now available in a coordinated form to ensure related testing/simulations of all the necessary aspects of the building for which each professional is responsible. Nisbet spoke of Sonata’s role in “Partnering” and industry standard component databases. Thorpe and Perrin showed how ArchiCAD assisted in data integration processes. Haidekker, Janasa and Hendry showed solutions to this main or second stage problem area and leading into the final working details for the site. Palmer showed some progress with this third problem area and the advantage that will bring to the middle stage design development in turn. Pyle and MacLeod’s work on Component Based Design explored Design Manufacturing and Assembly and showed the massive benefits to profitability, working backwards through the process, based on thorough understanding of the building and the components. However they are still waiting for the appropriate tools.

The third recurring problem identified, fell in the later detailing stage of the process. Here inadequate processes for describing and illustrating how the building is to be implemented in practice on the site, sometimes allow designers not to think this important aspect through satisfactorily, leaving much to the imagination of the site team, or necessitating building delays and inactive workers, whilst site meetings and further detailed elaboration are progressed. By associating detailing written descriptions to the components in the detailed 3D electronic building model; there is no ambiguity and such information can be tested out before building on the ground, saving costly long debates on site and even physical disasters, where detailed design problems remain unresolved. One of the contributors was shocked to read of a practice which proudly claimed they only used physical models even for indicating details, despite in his opinion the inability of physical models to define the complexity of today’s building technologies. The way forward was illustrated as mentioned in the previous paragraph, by other contributors using component design and scheduling directly off the object based model. Crotty’s target required the team to produce output which clearly works on a ‘What you see is what you’ve got to build’ principle.

The unique contributions to knowledge reviewed here, actually show interesting drives towards taking greater advantage of computing in the extremely complex process of building design and construction. Results show improved application of software to successfully structure, organise, rationalise, shorten, simplify and improve the quality, performance, delivery and cost of building and ultimately; of user satisfaction.

We begin to see the dawn of a brighter future for better quality and functionality of buildings for the clients and users and a greater ease in successful, more cost effective working processes for the building design and production team.

Those professionals who are migrating into these new ways of working, through electronic virtual modelling of the necessary processes; should also realise their actual fruits in more certain and reasonable costing, improve their reputation competitiveness and hence attract a greater market share of available work.
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COMPUTER IN CREATION OF ARCHITECTURAL FORM

AUTHORS
Aleksander Asanowicz
Faculty of Architecture
Technical University of Bialystok
asan@cksr.ac.bialystok.pl

ABSTRACT
This paper considers graphic methods of presentation of ideas' in the creation of architectural forms' and evolution of these methods, determined by the implementations of information technology. Drawings have been the main medium of expression since Leonardo da Vinci to the present-day. Graphic communication has always been treated as a main design tool, both - at the ending stage of design and at the early design stage. Implementation of computers in design doe not change this situation. The entire design process proceeds in a traditional way. While searching for the idea we use hand sketches and, after this, technical drawings are draught on a plotter, which replaces a drawing pen. Using computers at the early design stages encounters serious difficulties. The main thesis of this paper is that hardware and software inadequacy is not the problem, the problem is in the inadequacy of the design methods. This problem is to be reconceived as what a person can do with a program, rather than what is the capacity of a program. Contemporary computer techniques allow us to put an equation mark between the searching for idea, visualisation and its realisation in virtual space. This paper presents “Sketching by scanning” - an experimental method of using computer hardware and software for stimulating of searching of architectural’s form.
COMPUTER IN CREATION OF ARCHITECTURAL FORM

Finally, computers go wrong. 
What do we mean by “go wrong”. 
One characterisation is that they 
behave in ways we did not anticipate. 
R. Glanville, 1997

Creation
The basic conditions of creation are intuition, that is the ability to foresee without trying to understand, and imagination, that is the ability to create certain images in our mind. Therefore, the core of creation is based on creating an idea in our thoughts, which had never before been brought to life by anybody, as well as images, which are not associated with any past experiences. (Maslow A.M., 1962) Creation understood as production of form is described by S. Lem as a scheme which consists of:
1) a generator of excessfull diversity, 2) criterional filters sifting that diversity, 3) a program of the given transformation modifying the selected elements, according to the instruction included in this program (Lem S., 1988)
Those elements - generator, filters and program might be generally independent one from another. The generator may produce diversity in the strictly accidental way or according to its knowledge. The filters may sift “diversity” with regard to freely assumpted criterious. The transformational matrix may perform a defined by itself transformation over the sifted elements. However, that scheme works in a different way in the architectural creation. There is a changeable feedback - reaction of the created elements to what have created them. It means that the designed form is not only the result of an architect’s reaction to the unformed matter, but also the result of the reaction of the created form to its own creator. One should remember that owing to the experiences assumed during the further projecting activities, an architect may introduce some changes in elements that have already been designed. That correction is influenced by the feedback (object - architect - object) and also by the fact that the begun work has an endless amount of possible ways of development. Moreover, the development of the form is proportional to the reduction of invariants’ number. The influence of the earlier activities over the further ones may be double. They support the author when a development of the project corresponds to his ideas. Then we experience a feeling that the object is projecting itself. They may be also an obstacle when the development of the form is inconsistent with the authors’ ideas. Analysing the first stages of creation we can state that its beginnings as a strange incident, repeatedly undefined. We do not know what kind of set of elements we dispose. We cannot fully control all features of the selecting filters. Moreover, we do not know the transforming matrix which we launched during the process of creation. When analysing the structure of designing, H.A. Simon assumed designing as an ill-structured problem. These problems are characterised by a poorly developed structure from the point of view of such parameters as the aim, possible alternatives and evaluation functions. (Simon H.A., 1973).
Reitmann believes that architecture practically knows no definite idea of the aims to be chosen, of the proper methods and of what is usually the starting point for a designer. (Reitman W.R., 1964)

The whole process of creation is individual, it evolves differently at each architect’s mind. But the history of architecture proves that in a creative process of design an inseparable component of this process is graphic techniques. A drawings have always been a very important communication tool, and it is still the natural and obvious medium for expressing visual thinking. With its help a visual pictures formed within the architect’s mind change and become more precise. Simultaneously, as a feedback, drawings reflect our memory, complementing spatial pictures already conceived in it. Drawings, being the catalyst of the designing process, also play the role of its organiser. For example, a plan puts in order information on circulation, structure and visual forms better than most other presentation methods. The perspective separates the visual images of the designed image in a way that no orthogonal drawings can. As Omer Akin states, the choices of the presentation method is equivalent to the choice of the problem solution method. (Akin O., 1986)

Every type of creation has constructed the proper means of expression and its own methodology, perfected with every generation. This process of perfection is in each type of art extraordinarily important as each artist seeks for a means of communication with his or her contemporaries. Each type of art has specific and unique characteristics of artistic expression, its own language. A novel leaves the reader with a synthetic impression, evoked by the read text. A film adaptation of a novel leaves totally and qualitatively different images, the similarity of which to the literary original depends on the imagination of the receiver. The sum of impressions evoked by a text and film also gives a qualitatively different image, enriched by the set of impressions which are the result of the perception of these very different types of art.

Architectural creation is also characterised by its unique method of communication. It includes a very specific lexicon, both verbal and graphic. In the process of communication, the very important items are the precision as well as the richness of the contexts of graphic images, as it is these that the full realisation of the architect’s idea depends on. Each symbol and each line carries a specific meaning. The creation of a work of art in architecture has always happened by means of lines and symbols. It would be very difficult to imagine just how many drawings had to be drawn in order to realise all the stages of the development of architecture. It is the intuitive meaning of lines that represents the idea of architectural creation.

The sketch
The sketch is a graphic means of seeking the architectural idea. The drawing has always been the basic means for expressing the thoughts of an architect, whose whole activity during the many centuries of existence has been divided into two stages. The first stage has always been designing - finding, perfecting and presenting the idea of an architectural structure. This process has been expressed by means of a drawing. The second stage has been building - the realisation of the architectural explorations in the material, corresponding to the technical drawings done in the designing process.

Until the mid 19th century, the architect was at the same time the designer and the builder. He designed and, at the same time, supervised the construction of his work. Therefore, when designing, he used graphic
representation only when he felt that the drawings could be of any use to him. They merely had a supporting role. What was not included on the drawing was supplemented by the architect himself - he explained his ideas to the workers either verbally or by means of a sketch. However, despite the sloppiness of those images of architectural objects, the architect could not work without drawing.

The necessity to perfect the idea and the fixation of all the stages of this process eventually forced the architect to use graphic representations. By the end of the 18th century, a tendency to narrow down the specialisation of the architect to the designing stage, accompanied by the preparation of sketches and technical drawings, is seen. The sketch becomes a means of making the representation of „the seen” (the reality) and then the expression and perfection of creative ideas possible. Different methods of organising the particular stages of the designing process are developed. Each stage has its unique means of expression (sketches - in the early stages of designing, technical drawing - at the stage of preparing the documentation). In the deliberations presented further, we shall focus on analysing the significance of the manual sketch for the creation of architectural form in the traditional designing process. In architectural practice the sketch played a deciding role. Most architects believed that designing is impossible without sketching. They expressed their resort by means of sketches on a piece of paper, with each stage characterised by a specific type of sketching forms. First, the idea of the sketch was developed, where the main contours of the form were searched for. The form became continuously detailed with each consecutive sketch. The image of the form was enriched with detail and information on the colour and texture.

In the creation of the architectural form, the first drawing is a blurred and imprecise image of the construction, reflecting only its main idea. On the other hand, the contents of the image are sufficient to an extent that they can be expressed by means of a simple symbol. This elementary character of the image is natural because, as it is seen throughout the many centuries of practice, making the visual images more concrete takes place gradually - from a small hieroglyph to bigger and more precise drawings.

In the latter part of the present paper, three different cases of the use of manual sketch for the purpose of searching for the architectural form are analysed.

Case 1

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Figure 1: Sketches of the Ronchamp chapel made by Le Corbusier.
For example, let us now take a number of Le Corbusier's sketches made during the designing of the Ronchamp chapel. The first drawing presents the idea of the compositional influence of the body (form) of the building and its surrounding landscape. The landscape is a contour of a hill with a few lines presenting the faults of the land and a path. (Fig. 1a). In the next drawings, the image of the chapel is developed. The author turns the building, making its form more detailed. The precision of the presentation is still so weak that the contours of the chapel are only clearly marked on the drawing of the southern facade (Fig. 1b). On drawing 1c and 1d, the author makes the fragments of the form more concrete, not paying much attention to the precision of the contour. The lack of a clear decision defining the contour causes a lack of precision in the presentation method. The lines marking the contour are crooked, broken, thick in the places of repetitive drawing. The sloppiness of the drawing is natural however, as it reflects the author's real idea of the form at that particular stage of his research. The next series of drawings (1e- 1h) presents four facades of the chapel. The basic contours of the body was decided. Regardless of the broken lines and careless lining, characteristic of Le Corbusier, the plasticity of the form is perceived clearly. The graphic art of this series of sketches shows just how much the author's idea of the object has become precise. The linear drawing has become clearer, it carries more information.

The presented sketching method is characteristic for the process of searching in which the subconsciousness plays a main role. The architect makes numerous small drawings as if automatically. The many marks (representations) placed on the paper directs, in result, the author at the idea which will then be developed consciously. In effect, the subconscious images stored in the long term memory turn into fantasies that the author is still unaware of, which later become the idea of the form.

Case 2

Figure 2: L. de Costa, sketch of the Brasilia composition.

Another method of using sketches is observed when the author, from the very beginning, consciously chooses a particular direction of his search. Knowing what he wants to find, he pursues an aim, analysing critically each consecutive stage of sketching. The sketches of the Brasilia city, made by L. De Costa, can serve as an example here. When looking at them, we see the image being created with all consequence. The two intersecting lines transform into a drawing of a dragon-fly, being the essence of the assumed directions of composition.
The third form of searching takes place in the case of a long term inability to find an idea. The author is unable to overcome the material resistance and the consecutive sketches bring about nothing new. Such dry and infertile periods are more than exhausting for a creator. However, in reality, the imagination is still a witness to processes preparing further creative peregrinations. A moment eventually comes when a small impulse evokes associations and the mind begins to work in the right direction. This is what happened in the design process of the Brasilia cathedral. The first sketches did not satisfy O. Nimeyer, who drew a circle in the open area meant for the church. The circle transformed into a sun, surrounded by an aureole of rays, what suggested the central plan of the building and pylons open to the top as if sunflower leaves (Fig. 3).

**New methods of searching for ideas of form**

In the last 20 years, great changes with regard to processing of information related to architectural design took place. A great volume of technical documentation, without which the realisation of the design is impossible, has been more often and to a greater extent been performed by computers and graphic software. Television, photography and film are used in designing. Under the influence of the new techniques, the character of the graphic art and modelling is constantly subject to changes, which in turn determines the changes in the technical means used in architectural design.

Traditionally, CAD software development has mimicked the hardware tools (pencil, paper, paint brushes) used in the practice of architecture. Many designers think, that a computer is a tool, just a piece of charcoal is. Using computer as traditional tools would be used, they feel disappointed. If they are doing conceptual work, it is more difficult to make just a hint or suggestion of something with computer than to do it by hand. A computer wants to render real things. It is extremely difficult to create a drawing that hints at a basic form or idea. A computer drawings is too finished to use at this stage. (Asanowicz A., 1997) In result, design process proceed in traditional way. While searching for the idea we use a hand sketches and, after this, technical drawings are draught on a plotter, which replaces a drawing pen. Using computers at early design stages encounters serious difficulties, what is clear to everybody who tries to make a sketch in AutoCAD or another CAD software.
Comparing computer to a pencil or technical pen, at 1st AVOCAAD Conference, I wrote “A pencil is a pencil. A computer is a computer. A computer isn’t a pencil. A pencil isn’t a computer.” (Asanowicz A., 1997) Of course, that when we make a drawing of a project, we use a computer as technical pen. We draw lines, arches, curves .... Thanks to that we are able to produce technical documentation a lot faster than before. Without any doubt it is an Added Value - created by computer in a design process. But it is not enough that one could expect from such an advanced technology. The thesis of this paper is that it is not hardware and software inadequacy that constitute a problem but the inadequacy of design method. As B. Laura wrote - this problem must be reconceived as what a person can do with a program, rather than what is the capacity of a program. (Laurel B.,1993) This type of thinking has become the stimulus for undertaking an effort of developing experimental methods of the use of computer hardware and software for stimulating the search for the architectural form. In this method we try to use a computer as a medium. A tool becomes a medium as it is used for things that were not its original intention. When a tool becomes a medium, it gains immeasurably in potency and in its ability to help for our thinking - and thus to take a role as a partner in enhancing our creativity. (Glanville R., 1994)

Case 1
The “Squares and Spheres” design was done by means of the Imaging Imagination Workshop in 1997 at Delft University of Technology. The task was to design a scenario of using the town market square, composed of two squares connected at the corners. Having the outset situation precisely determined and absolutely no idea of how to solve the problem, we decided to use a scanner for the purpose of the project. We placed a cardboard cut-out of the square’s contour on its surface. Next, the colour pieces of paper placed on it were scanned. (Fig. 4a, b) Because the images obtained seemed too homogenous and static, we added small spheres (beads), being the metaphor of the movement taking place on that square. (Fig.4c, d) That way, a second series of scanned images was obtained. The images were achieved by coincidence, however not without the intervention of the authors, who were responsible for choosing the amount and the quality of the elements used. Few images best satisfying the imagined ideas of the authors were selected from among the images of the second series. They were later subject to computer graphic processing. After a number of transformations, bit maps corresponding to the already shaped idea of form were obtained. (Fig. 4e, f, g, h) On that basis, a visualisation in a 3D studio programme was developed. The presented process of designing can be compared to the analytical method used by Le Corbusier when designing the Ronchamp chapel. The form develops and is made more precise, parallel to the development of the digital sketches - from the abstract ones to the more and more detailed ones.
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Figure 4 a-h.
Case 2
The design of the museum, just like in the case of L. De Costa’s Brasilia, was created according to the consciously defined direction of searching. L. De Costa assumed the drawing of two intersecting lines as the basis of his concept of the city. Similarly to that, in the design of the museum, the main indicator was a sea- holly leaf. From the series of images obtained by means of scanning the leaf placed on the scanner in different positions, one was chosen, which was later subject to processing by means of the Trace Contour operation under the Photo Shop programme. A digital sketch of the plane of the museum was obtained. The design was made on the basis of that sketch (Fig. 5). (The design was dome by a 4th year student, Tomasz Stryjewski, under the guidance of Dr Jerzy Ullman from the Faculty of Architecture, Technical University of Bialystok). The design is an example of the reduction method of designing according to Poincare’s thesis - First I have, then I find. If a 3D scanner was used, than the inspiration could become a form in itself.
Case 3

A design of the city is a perfect illustration of the role of the coincidence in the designing process. "The accident is an early, especially decisive factor in every evolution process where the arrangement during the creation produces its own patterns which cannot be found at the very beginning of it." (Lem S., 1988) The preliminary sketch was created by scanning a ping-pong ball and a piece of aluminium foil on a black and white scanner. It was probably the first unconventional use of the computer hardware in our Faculty. The image, called "Bacon and eggs", was a joke and was not supposed to be used for any designing purpose. (Fig. 6a) However, after a series of graphic transformations, an image called the "Aztec Circle" was created. (Fig. 6b) After exporting the sketch to Corel Trace for the purpose of its vectorisation, a 3D Mosaic procedure was initiated by chance. (Fig. 6c) On the basis of the obtained image, resembling a city from the SimCity 2000 computer game, a design of a regular urban structure was created (Fig. 6d).

Conclusion
1. A specific character of the composition activity of an architect is associated with the methods and modelling ways of spatial forms. Creativity is realised as a process of "making an ideal model real". Therefore, the creative modelling of a form, where the characteristics of the composition are shown is so important. The analysis of the design process shows that the graphic art. has always been one of the basic designing media because it ensured the operational and flexible fixation of design ideas. Each sketch, being the expression of a defined view of the form, allows for an evaluation and formulation of the new aspects of the idea of composition. At the same time, a deeper interpretation
of the architectural image requires the development of a sufficiently long sequence of visual models. In traditional graphic art, as design experience shows, such presentation of the transformation of composition is extraordinarily difficult. The graphic computer transformation, together with the creation of the history of the undertaken activities, allows for a fuller exploration of design metaphors, for the metaphorisation of the process of form creation.

2. Designing at the early stages is becoming more and more metaphorical. Out of the chaos of forms the proper forms are selected by our mind, corresponding to our ideas. Whereas the manual sketch made it possible, with a bit of skill, to graphically represent the idea of the creator, it did not, being a tool, create an additional value in the very design process (excluding its aesthetic value that it possessed).

The use of scanner makes it possible to discover forms which are surprising, sometimes even to the author. This method proves that the computer can be useful as a "metaphorisation machine" and can serve the role of the "Superior" in the process of creation, taking upon itself the role of the generator of chances. And as Lem once said: “The accident is an early, especially decisive factor in every evolution process where the arrangement during the creation produces its own patterns which cannot be found at the very beginning of it.” (Lem S., 1988).

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COMPUTERIZED SIMULATION OF URBANISM PHENOMENA

AUTHORS
Ruthie Orev
14 Itamar Ben Avi St.
Jerusalem 92348
Israel
rutiorev@netvision.net.il

ABSTRACT
Despite the complex forces that operate in urban development, a relatively small number of geometries and morphologies may be identified in urban maps. Do covert universal laws exist which are integral to the concept of the city and responsible for the geometry? May one formulate such laws and program a computer to produce maps on the basis thereof, thus exposing architectural reality to a scientific process of objective experimentation? In an effort to answer these questions, I wrote programs based on definitions, parameters and rules reflecting architectural phenomena. The creation process using the programs is based on a formalistic approach, drawing on a random mechanism, considerations of probability and numerous calculations. This “computerized planning” does not mimic or simulate human work processes. The programs enable a considerable measure of visual variety to be achieved, replicating familiar urban morphologies. One may isolate variables, starting conditions and growth processes, and examine the influence thereof on fabric, organization and order. The existence of a program such as this raises questions of principle concerning randomness and creation, the future role of architects, the creative capacities of computers, the connection between science and architecture, truth in virtual situations, etc.
COMPUTERIZED SIMULATION OF URBANISM PHENOMENA

Preface
During the early period following the introduction of computers, many mathematicians engaged in the writing of “life game” programs. As the chaos theory developed, scientists in various fields of research (physics, chemistry, agriculture, economics, etc.) have attempted to create computerized models describing real processes. To the best of my knowledge, there are few works of this type in the field of architecture.

After examining maps, programs and aerial photographs of cities and locales, I noticed that the geometry of most cities could be classified according to a relatively small number of morphological groups. This observation is surprising, since urban development is known to be influenced by diverse and complex processes, which vary from place to place and from era to era. This realization led me to ask whether urbanism is the subject of covert universal laws integral to human needs and differential in their architectural expression, which are responsible for geometry and dominant in the development of a built environment. If the hypothesis that such laws exist in urbanism is correct, and if these laws may be formulated, it may prove possible to replicate urban development in a context divorced of the “genuine” processes of history, culture, economics, technology, geography, etc. Thus architecture might be exposed to a scientific process of objective experimentation.

I decided to attempt to write a program that would create familiar urban morphologies and that would replicate, through simple mathematical laws, localities and/or the development processes thereof. I chose to work within the AutoCad environment and to program in Lisp. Since it is not an optimal environment, and my programming capabilities are not those of a professional programmer, the programs are provisional and of limited capacity; accordingly, the maps created do not exploit the full potential of this process.

Urbanism and Computer Programming
In order to develop a program capable of simulating urban processes, it was necessary to re-examine the basic tools and concepts of urban design. The urbanist draws on a wide range of tools in his work: Maps, models, photographs, tables, surveys, etc. In this study, I chose to concentrate on maps, which I consider the central tool used by architects. Maps are not only the objective documentation of the city; they also represent a translation of the perception of the person who creates them. Maps imbue those who read them with a mental understanding of urban order and organization. Through our imagination and experience, we can add sensory features, thus obtaining an image of the place. Virtual maps may be addressed in the same way.

Of the various physical elements one can identify in a city, I chose to concentrate on buildings, roads and open spaces. These three elements are dominant in fashioning the physical order of the city, both on the local level and on the general level. Their absolute characteristics are independent of
culture, place or time, so that they lend themselves to a process of abstraction and formal definitions. I distinguish two types of road: 1. Pre-determined roads, whether as the result of cultural decisions or as a result of the geographical and topographic structure of the site. These roads organize the city and influence the process of construction. 2. Local roads, created by and responding to the state of construction.

In order to develop a computerized model for urban design, one must identify the forces influencing the processes of growth of the city and the order of creation of their components. In selecting a location for the construction of a building one must examine the viability of the location for that building. Economic considerations, land and construction costs, the viability of the result, etc., play a central role in this choice. It is influenced by various factors: Density, distance of infrastructures, accessibility, proximity to existing centers, prestige, etc. Construction in or adjacent to existing fabric offers many advantages: Reduced costs for infrastructure, easy access, protection from enemies, proximity to the family, etc. However, densification is not always possible. Sometimes no land reserves are available, or the available area is not economic; in such cases, building must move outside the existing area. Densification also has negative properties: Limited vacant space, pollution, noise, etc. This description is an abstract generalization of processes, which in reality are highly complex.

Any city has characteristic components that distinguish it from other cities. These local forces are of a geographical and cultural nature. In the computer programs, I allow starting conditions representing geographical situations and physical/cultural situations, such as: rivers, lakes, parks, regional roads, organizing roads, organizing buildings, etc. These starting conditions represent areas that are prohibited for building, and axes and points of reference that shape the surrounding urban fabric. I enable the definition of dominant parameters that control building and represent local social values such as: density, relative quantity of public buildings, dependence on existing infrastructure, extent of variation, etc. The starting conditions and parameters are defined at the beginning of each experiment, reflecting the fixed properties of a given location; they may, however, be changed during the running of a program. The changes represent the capacity of society for change. The fact that different parameters and starting conditions may be defined enables the construction of various simulations relating to a variety of locations and cultures.

I choose to convert governmental decisions and geographical situations into static and predetermined elements as starting conditions, and to convert economic forces and psychological needs into dynamic processes that determine building. This choice is somewhat arbitrary; one might have selected other forces as dominant, both by way of static factors and dynamic processes.

Development of algorithms
Throughout the work of this study I developed three algorithms simulating three phenomena in architecture. 1. Two-dimensional spread of a settlement. 2. Growth of road nets. 3. Local situation of built elements. In this paper I present only the third algorithm.

Introduction algorithm: Placing squares of a fixed size in a vacant location within a given grid. The goal was to obtain random distribution of points across a plane. Some of the results resemble a non-dense rural settlement.
The result were meager and did not resemble urban architectural creation. This preliminary experiment served as a tool for becoming acquainted with the possibilities and limitations of computerized simulation.

**The double-cell algorithm**

In order to simulate economic and social forces, and in order to enable relations of affinity and densification forces, I defined a growth method based on the existing. The basic element includes a **double cell**: A drawn square with an opening toward a covert adjacent square. The architectural interpretation of this elementary cell is that the drawn part represents a building or room, while the adjacent covert part is the open space serving as an entrance. The conditions of survival of the cell demanded that an “entrance” free of construction be maintained for that cell. The algorithm enabled a single form of growth: **cell-by-cell**. A cell is built adjacent to an existing cell, enabling the creation of a continuum comprising two drawn cells, one drawn cell and one covert cell, or two covert cells. In the maps created by this method, one may identify clusters of built cells. Two types of continuum open area were obtained: 1) Linear – a road; 2) Closed continuum across a plane – inner courtyard. The maps so created had the appearance of a system of rooms rather than a group of buildings.

In reality, construction is not composed of squares of a fixed size within a strict orthogonal grid. I began to make the code more complex in order to allow variations on the basic cell and to allow diversity in the size of the cell, in length-width ratios and in angles. These changes are limited by variables provided by the user. This mimicking of reality produced maps with a richer appearance, including maps that had the appearance of maps of settlements. The next stage integrated the concept of the road and construction thereon. Roads constitute the skeleton of constructed fabrics and the dominant component in urban order. Most cities have a road network with a general method generating the development of construction and imposing order. In order to facilitate **organizing roads** of this type, and not only roads that develop as the result of construction in areas remaining vacant, it was necessary to allow predetermined artificial road elements simulating economic and social forces. This road system is a given that influences the process of...
growth, and serves as the infrastructure for construction, enabling settlement in adjacent areas. To this end, I introduced the line as representation of road, the concept of starting conditions, including lines and cells, and developed a cell-by-line growth process. A cell is entered alongside a line, relating thereto in terms of angle, location and direction. The road is represented by a drawn line with a width parameter, and the algorithm enables construction within a given system of roads and buildings.

Figure 2: 500 cells in a simple “cross” starting condition.

In a developing city, buildings grow in vacant places disconnected from the existing continuum. These buildings may form the nucleus for a new continuum. In order to simulate the location of buildings without relations of affinity, I defined a third type of growth: Random place. In this type of growth, a random point is selected within a circle centered in the heart of the existing map, and with a radius proportional to the root of the number of cells in the map. In each stage a selection of one out of the three growth methods occurs on a random basis based on a system of probabilities provided by the user. When one examines the built components and adjacent open spaces in urban maps, a variety of magnitudes may be found. In traditional construction, public buildings (governmental and religious buildings, etc.) covered a larger area than the almost-uniform background of residential buildings. In modern construction differences may be seen in the dimensions of buildings in the city, although there is no longer necessarily a correlation between size and the extent to which the building has a public character. The relative number of elements of different sizes may be controlled, as may the selection of different scales. Computerized selection takes place on a random basis according to a system of probabilities provided in advance by the user. Cities include non-constructed components that have a clear definition and function, such as plazas, parks, cemeteries, sports fields, and so on. These elements are defined in a similar manner to buildings, and constitute deliberately created open spaces that will maintain their vacant status for a long period. While cities contain forces mitigating in favor of densification to the point of saturation, there are also forces that operate to reduce density and maintain open spaces, enabling quality of life in the city. The proportion of built and open space varies from city to city and from culture to culture. A
mechanism must be applied that creates open spaces that do not constitute land reserves but are perpetually open, thus preventing overcrowding in the city.

Accordingly, the next stage was to integrate an element controlling density. I defined virtual cells: the computer finds a location for a cell, adds it to its database, but does not draw the cell on the map. The higher the probability that a virtual cell will be added to the map, the lower the density.

The process of development of the city also includes a process of dismantling and decay. Areas that were built are demolished and become open spaces and land reserves for construction. In order to simulate this process, I enabled the deletion of cells from the map and the database. The decision as to whether to insert a new cell or destroy an existing one takes place on a random basis according to a system of probabilities provided by the user. The most effective use of this option is to examine the reverse process on a given virtual map.

A city grows within a geographical reality that may include lakes, rivers, cliffs and so on. No building can develop in such areas. In existing cities, planners and residents sometimes define areas for conservation, whether for natural or cultural reasons. In order to simulate such situations, the program enables the definition of areas prohibited for building or demolition.

A city develops gradually, and over the course of time the residents define the roads according to the changing reality of construction. During the life of a city, external governmental intervention may be reflected in the establishment of public buildings and the definition of new points of reference in the city. Over the course of time the population changes, culture develops and values acquire a new character. Some of these changes are reflected in architectural terms such as: attitudes toward density; the relative number and dispersion of public buildings; the definition of areas for conservation, etc. In order to simulate these processes, I enable intervention in the starting conditions and amendment of the parameters and the probability sets during the running of the program. This intervention is enabled at predetermined intervals.

Figure 3: 1200 cells in an Arab-like grid of roads.
Figure 4.
The overlapping cell algorithm
Not all buildings are rectangular. An examination of the shape of buildings in a plan shows that most may be described as a series of superimposed rectangles. The open spaces adjacent to buildings may be described as an additional collection of rectangles surrounding the building on all sides. From another perspective, the form of the building and its open space constitute an internal and external polygon. In the double cell algorithm, particular attention was paid to one direction of the building that of the entrance. Yet some buildings in a city do not have one focal direction. Accordingly, I wrote another program for non-rectangular construction. I used the capacities of the double cell program (growth methods, variation of size and cell form, etc.) and redefined the basic cell as a collection of rectangular pairs, each superimposed on the other. The result was a block of construction surrounded by an empty strip of varying width. The general appearance of the results did not show any significant differences between the programs. On the micro level (the buildings created and the local fabrics), the results of the double cell algorithm seemed closer to actual construction.

Figure 5: Overlapping cells in a “star” road net.
Finally, in order to test the qualities of these programs, I attempted to run the algorithm using starting conditions of a real place. The specific location was unimportant to me; I chose the vicinity of the Stock Exchange in Ramat-Gan a city next to Tel-Aviv. The intervention process was interesting, and the ensuing results were impressive. The virtual maps did not essentially differ from the existing construction. This tool enabled an examination of the importance of the starting conditions, the use of different parts of the existing situation as a basis for growth, and so on. It was also possible to examine the parameters and systems of probabilities and the influence these exerted on construction. Such research may provide a tool for determining the places and phenomena within a city that function as dominant elements in creating order and fabric. The importance of each component of the city may be isolated and examined, thus creating a measurement tool for conservation decisions.

Figure 6: Ramat-Gan - Existing map.
Some conclusions from the experiments and examples
1. All the examples have a fractal character.
2. Some of the examples created are reminiscent of conventional natural architecture (architecture without architects).
3. Equal starting conditions and an equal system of parameters and probabilities in different experiments lead to differing results, though the differences are not qualitative.
4. The linear starting conditions are the dominant components in the general results; parameters and the systems of probabilities are responsible for local texture.
5. Experiments, which do not include variety in the size and angle of cells, create maps with the appearance of the inside of a large building or palace, while allowing for variation in size and angle creates maps with the appearance of locales.
6. The algorithm does not control absolute density, only statistical density. Some area remained vacant although the running of the program came to a stop due to saturation.
7. The experiments showed that during a process simulating growth – i.e., one in which the probability of construction is much greater than that of demolition – the contribution of deletion events does not influence the appearance of the map.
8. The superimposition of rectangles creates complex buildings with an authentic appearance.
9. Guiding intervention by the operator during the random process creates complex maps with hierarchy, resembling urban maps.
10. The decisions and definitions, which create the algorithm, based on rendition of the processes and definitions in architecture, i.e. the mathematical model is not independent, but is rooted in architecture.

11. It is possible to formulate simple and minimal rules and definitions that can create complexity.

![Figure 8: A growth from one point: 50, 200, 400 & 1000 cells](image)

**Conclusion**

My goal was to find a computerized process that would create maps that have the appearance of existing maps, thus repeating familiar typologies and morphologies. I sought non-arbitrary components resulting from basic human needs, the basic physical needs of life in a community, and universal economic forces. I selected architectural properties that may be formulated in a formal and geometrical manner. The method present in this study is similar in conceptual terms to that of an urban building plan. In both, definitions are formulated and formal laws are applied to such urban elements as: roads, streets, housing units, plots, building lines, density, etc. On the other hand, construction in the computerized model develops as the result of individual needs, adapting to and taking into consideration the immediate environment. This process resembles the development of architectural phenomena in the absence of a comprehensive mechanism: i.e., architecture without architects. I expected my “instant maps” to be less rich and interesting than those representing life, history and culture. I hoped that the common aspects of these two types of maps, and the revealed connection between life and simulation would reflect universal properties, enabling a new and different understanding of cities, or urban life, and of processes of planning and creation. The goal was to create a “machine” that simulates urban building in a computerized manner and creates virtual maps, thus providing a research tool for urbanism and may become a new planning medium.
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CREATIVE DESIGN IN OBJECT-ORIENTED ENVIRONMENTS

AUTHORS
Zenon Rychter
Faculty of Architecture, Technical University of Bialystok,
Krakowska 9, 15-875 Bialystok, Poland
rychter@cksr.ac.bialystok.pl

ABSTRACT
Object-oriented approach to software development is discussed as a conceptual framework and working computational model for creative architectural design. Two modes of object orientation in design are elaborated. The more conservative mode is static, based on class-type/object-instance hierarchies. The other mode is dynamic, based on a modern view of computation as multi-threaded evolution of interacting objects.
The Internet and Web as computing environment

Today, an architectural design process involves users, designers and computers. While users and designers, being humans, are rather conservative and set in their ways, computers are undergoing explosive growth and revolutionary change. Computing power has become ubiquitous. The information highway commonly called the Internet reaches everywhere. The World Wide Web (Klander 1997) is still in its infancy being only 7 years old but it is here to stay as technology grows, with over 80 million sites on the Internet now and limitless boundaries as to what you can do. The most important ingredient to the success of the Internet has been its neutrality. No matter what country you live in, what language you speak or even what operating system you are running, you can access the nearly unlimited information published on the Internet. We owe this to WWW standards. These standards encompass everything from programming languages used on the Internet to connection protocols like TCP/IP or modem command strings. The core development has been language standardization. Back in 1986, with literally thousands of word processing programs out on the market, each of which encoded text in a different way when saved to disk, it was virtually impossible to create a single text file that could be viewed by every operating system in existence. And if something as simple as text could not be portable, then one could forget about graphic files or program files. At the time, the Internet as we know it was not possible, simply because the operating systems and programs of the day had major difficulties translating files written in a foreign program. This is where Standard Generalized Markup Language (SGML) came in, a meta-language, a guideline for how other languages should be developed. The foundation for the web sites we see today comes from SGML, without which there would have probably developed an Internet for Microsoft OS systems, another for systems running Mac OS, and yet another for UNIX. Since its inception, several sub-languages have developed out of SGML. The most notable of these is Hyper Text Markup Language (HTML), however additional languages such as Virtual Reality Markup Language (VRML) and Extensible Markup Language (XML) were also developed out of the mold of SGML. HTML was originally intended only to handle the formatting of text. Only now is HTML broadening its horizons to encompass more than text. HTML 2.0 was the first revision of HTML to actually be solidified into a standard, which was released in September 1995. HTML 3.2 was the next revision of the language, published in May of 1996. HTML 4.0 became a standard in 1997. Previous versions of HTML were developed to match the capabilities of the browsers currently deployed on the market. This has changed in HTML 4.0, which is the first attempt to really expand the functionality of the language by adding support for object tags, as well as support for Cascading Style Sheets (CSSs). The object tag is notable because it enables scripts, code from scripting languages, to be embedded directly in the HTML source code for a site. The development of the object tag has a direct relation to the Object-Oriented Model for programming languages, found in application programming languages for years now. Between the object tag

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and Cascading Style Sheets, the possibilities for the coding of a web site will be limited only to the imagination of the site developer. Dynamic HTML is Microsoft's latest advance in HTML, intended to make the language more functional by adding abilities normally found in application programming languages like C++ (Stroustrup 1993) or Java (Jamsa 1996). For the first time, a site developer can code an HTML document that uses animated text, can be set for timed events, scrolling text as well as the ability to access databases all without the need for additional components. Extensible Markup Language (XML) was announced as a proposed standard in December 1997. Like SGML, XML is not really a programming language, but a meta-language. However, whereas SGML was designed as a universal code for the formatting of text, XML is designed as a universal code for the formatting of data, a universal code for how Internet applications share information between one another. As the abilities of online technologies like HTML develop, the differences between web sites and applications are beginning to fade. However, a major hindrance to programmers who wish to develop online applications is the way that current programming languages encode their information. Because of this, it is exceedingly difficult for developers to create web applications intended to share information like databases, spreadsheets or even games simply because the developer has no control over whether or not the software installed on the user's system will be capable of interpreting and using the information delivered to it. This is where XML comes in. XML is designed as an open classification, whereby packets of data transmitted from one computer to another will contain all the information needed to be able to decode itself using any application that can handle XML. Just as SGML enabled electronic text to be useable by any computer with an SGML capable browser installed, XML provides this same function for data itself.

There is no limit in the Web specifications to the graphical formats that can be used on the Web. Vector Graphics (SVG) is a recent language for describing two-dimensional graphics in XML. SVG allows for three types of graphic objects: vector graphic shapes, images and text. Graphical objects can be grouped, styled, transformed and composited into previously rendered objects. The feature set includes nested transformations, clipping paths, alpha masks, filter effects, template objects and extensibility. SVG drawings can be dynamic and interactive. SVG allows for straightforward and efficient vector graphics animation via scripting. A rich set of event handlers such as onmouseover and onclick can be assigned to any SVG graphical object. Because of its compatibility and leveraging of other Web standards, features like scripting can be done on HTML and SVG elements simultaneously within the same Web page.

Mathematical Markup Language (MathML) is a recent low-level specification for describing mathematics as a basis for machine to machine communication. It provides a much needed foundation for the inclusion of mathematical expressions in Web pages. MathML is intended to facilitate the use and re-use of mathematical and scientific content on the Web, and for other applications such as computer algebra systems, print typesetting, and voice synthesis. MathML can be used to encode both the presentation of mathematical notation for high-quality visual display, and mathematical content, for applications where the semantics plays more of a key role such as scientific software or voice synthesis. MathML is cast as an application of XML. As
such, with adequate style sheet support, it will ultimately be possible for
browsers to natively render mathematical expressions. MathML consists of a
number of XML tags which can be used to mark up an equation in terms of its
presentation and also its semantics. MathML attempts to capture something of
the meaning behind equations rather than concentrating entirely on how they
are going to be formatted out on the screen. This is on the basis that
mathematical equations are meaningful to many applications without regard
as to how they are rendered aurally or visually.

With the launch of Java language and Jini technology, Sun kicks off a new era
of distributed computing. Businesses are leaving behind a motley system of
fax, phone, and proprietary software by shifting to Java technology. In Boston
Computer Museum, thanks to the virtual fish tank exhibit, visitors can interact
with playful, brightly colored fish propelled by Java technology. Embedded
Java will support real-time capabilities, providing consumer and industrial
devices, such as mobile phones, pagers, and medical devices, with a precise,
predictable response time and the ability to coordinate functions without any
lapse between operations. With Jini technology we can imagine a huge global
network with a host of myriad devices and it all just works. Java applets, those
nimble servants of the network, are popping up in browsers everywhere.
Servlets support dynamic web site applications in ways never dreamed of. The
Java platform is making major inroads into every area of computing, offering
portable, highly scalable, multiplatform, and simple to use, “Write Once, Run
Anywhere” application development. Jini Technology makes computers and
devices able to quickly form impromptu systems unified by a network. Such a
system is a federation of independent, flexible, smart devices, including
computers, that are simply connected. Within a federation, devices are instant
on, no one needs to install them. The network is resilient, you simply
disconnect devices when you don’t need them. This creates a work
environment where the tools are ready to use and largely invisible. Jini
technology provides simple mechanisms which enable devices to plug
together to form an impromptu community, a community put together without
any planning, installation, or human intervention. Each device provides
services that other devices in the community may use. These devices provide
their own interfaces, which ensures reliability and compatibility. Devices
permeate our lives: TVs, VCRs, DVDs, cameras, phones, PDAs, radios,
furnaces, disk drives, printers, air conditioners, CD players, pagers, and the
list goes on. Today devices are unaware of their surroundings, they are rigid
and cannot adapt. When you buy a disk drive, you expend a lot of effort to
install it or you need an expert to do it for you. But now devices of even the
smallest size and most modest capabilities can affordably contain processors
powerful enough for them to self-organize into communities that provide the
benefits of multi-way interactions. A device can be flexible and negotiate the
details of its interaction. We no longer need a computer to act as an
intermediary between a cell phone and a printer. These devices can take care
of themselves, they are flexible, they adapt. A device can take charge of its
own interactions, can self-configure, self-diagnose, and self-install. When
computers were the size of large rooms, it made sense to have a staff of
people to take care of them. But now technology creates the possibility of
impromptu, self-managing device communities popping up in all kinds of
places far from any system administrator. The final stretch of the
computational power dimension is that now processors are powerful enough

153
to support a high-level, object-oriented programming language in such a way to support moving objects between them. And such a processor is small enough and cheap enough to sit in the simplest devices. Once there is sufficient computational power, the ability to connect and communicate is the dominant factor. Today for most people, a computer runs only a few applications and mainly facilitates communication: email, the Web. Internet's popularity soared first with email and more recently once the Web and browsers became prevalent. When the Internet was developing, there were two essential activities: defining and perfecting the underlying protocols and infrastructure, and creating applications and services on top of that infrastructure: email composers and readers, file fetching programs, Web browsers, and the Web itself. No single company or organization did all the work, and none could, if the venture was to be successful, because underlying it all is a standard protocol, and a protocol can be successful only if it is widely adopted. The Java programming language is the key to making Jini technology work. Java was originally developed for programming intelligent home appliances. Java leverages software reuse across projects, tools, and architectural layers. Astronomers and engineers use Java to monitor and control second-by-second movements of the Hubble Space Telescope. A sophisticated Java applet controls a rover on the surface of Mars. Java gadgets in the works include a finger ring that opens locked doors, a home telephone that offers movie reviews and ticket ordering, a wireless pen-based network computer that manages on-the-floor inventories. Applets run from simple to sophisticated, and uses range from management of business transactions, to sharing and analyzing scientific data, to gaming and consumer-oriented purposes, generally to breathing intelligence into the devices you'll use every day.

The Internet(technology)/WWW(language) story demonstrates that technology cannot be exploited to the full without a proper standard, commonly understood language. We need the language first to conceptualize the system we are interested in and, second, to interact with the system, control it, or be a part of it. Object-Oriented Languages (OOLs) provide both the conceptual framework (Coad, Yourdon 1991) and computational efficiency to model the most complex systems, the heterogeneous Internet and architectural design included. OOLs, notably C++, have been the standard for system programming for some time now. But it is only recently that an OOL, Java, is becoming a standard on the Internet. The structure of the Internet is similar to the brain (Klander 1997). Thanks to Java we can understand the workings of this brain and can plug-in our own brains. The Internet plus Java form an incredibly rich computing environment, on Object-Oriented-Environment (OOE), ready to support all computing needs and styles.

OOEs are relevant to creative, conceptual architectural design on two levels, static and dynamic, which correspond to two modes or models of architectural design, static-sequential-manual-controlled and dynamic-multithreaded-asynchronous-automatic.

**Static object-oriented approach: design from components**
In the static-sequential mode, developing an architectural design is likened to developing a windowed application with a graphical user interface (GUI) or an interactive Web site. The basic concept is the metaphor of objects (Stroustrup 1993). This is a natural way we interpret and interact with the world around us. Objects, whether real-world or computer representations, are described in terms of what they are and how they behave. Objects have certain characteristics or attributes, called properties, that define their appearance or state—for example, color, size, and modification date. Properties are not limited to the external or visible traits of an object. They may reflect the internal or operational state of an object, such as an option. Things that can be done with or to an object are considered its operations. Moving or copying an object are examples of operations. You can expose operations in the interface through a variety of mechanisms, including commands and direct manipulation. Objects always exist within the context of other objects. The context, or relationships, that an object may have often affects the way the object appears or behaves. Common kinds of relationships include collections, constraints, and composites. As in the natural world, the metaphor of objects implies a constructed environment. Objects are compositions of other objects. You can define most tasks supported by applications as a specialized combination or set of relationships between objects. A text document is a composition of text, paragraphs, footnotes, or other items. A table is a combination of cells; a chart is a particular organization of graphics. When you define user interaction with objects to be as consistent as possible at any level, you can produce complex constructions while maintaining a small, basic set of conventions. In addition, using composition to model tasks encourages modular, component-oriented design. This allows objects to be adapted or recombined for other uses. Applying object-based concepts offers greater potential for a well-designed interface. As with any good user interface design, a good user-centered design process ensures the success and quality of the interface. The first step to object-based design should begin with a thorough understanding of what users’ objectives and tasks are. When doing the task analysis, you should identify the basic components or objects used in those tasks and the behavior and the characteristics that differentiate each kind of object, including the relationships of the objects to each other and to the user. Also identify the actions that are performed, the objects to which they apply, and the state information or attributes that each object in the task must preserve, display, and allow to be edited. An effective user-centered design process involves a number of important phases: designing, prototyping, testing, and iterating. The initial work on a software’s design can be the most critical because, during this phase, you decide the general shape of your product. If the foundation work is flawed, it is difficult to correct afterwards. This part of the process involves not only defining the objectives and features for your product, but understanding who your users are and their tasks, intentions, and goals. This includes understanding factors such as their background — age, gender, expertise, experience level, physical limitations, and special needs; their work environment — equipment, social and cultural influences, and physical surroundings. Ideally, you want to create a design model that fits the user’s conceptual view of the tasks to be performed. You should consider the basic organization and different types of metaphors that can be employed. Observing users at their current tasks can provide ideas on effective metaphors to use. After you have defined a design model, prototype some of the basic aspects of the design. A prototype is a valuable asset in
many ways. First, it provides an effective tool for communicating the design. Second, it can help you define task flow and better visualize the design. Finally, it provides a low-cost vehicle for getting user input on a design. This is particularly useful early in the design process. User-centered design involves the user in the design process. Usability testing a design, or a particular aspect of a design, provides valuable information and is a key part of a product’s success. There can be different reasons for testing. You can use testing to look for potential problems in a proposed design. You can also focus on comparative studies of two or more designs to determine which is better. Usability testing provides you not only with task efficiency and success-or-failure data, it also can provide you with information about the user’s perceptions, satisfaction, questions, and problems. When testing, it is important to use participants who fit the profile of your target audience. Because testing often uncovers design weaknesses, or at least provides additional information you will want to use, you should repeat the entire process, taking what you have learned and reworking your design or moving onto reprototyping and retesting. Continue this refining cycle through the development process until you are satisfied with the results.

Working in OOE is further simplified by using classes. For example, the classes in the Microsoft Foundation Class Library (MFC) make up an “application framework” — the framework on which you build an application for Windows. At a very general level, the framework defines the skeleton of an application and supplies standard user-interface implementations that can be placed onto the skeleton. Your job as programmer is to fill in the rest of the skeleton — those things that are specific to your application. You can get a head start by using the application wizard to create the files for a very thorough starter application. You use resource editors to design your user-interface elements visually, class wizard to connect those elements to code, and the class library to implement your application-specific logic. Your role in configuring an application with the framework is to supply the application-specific source code and to connect the components by defining what messages and commands they respond to. You use standard OOL techniques to derive your own application-specific classes from those supplied by the class library and to override and augment the base class’s behavior. It is crucial to understand the relationship between your source code and the code in the framework. When your application runs, most of the flow of control resides in the framework’s code. The framework manages the message loop that gets messages from Windows as the user chooses commands and edits data in a view. Events that the framework can handle by itself don’t rely on your code at all. For example, the framework knows how to close windows and how to exit the application in response to user commands. As it handles these tasks, the framework gives you opportunities to respond to these events as well. But your code is not in the driver’s seat, the framework is. You can use the framework to write sophisticated programs, even if you are not an experienced programmer. The reason is the component library: a collection of routines that make it easy to work with the Windows environment. You don’t need to understand the low-level workings of Windows. You don’t have to be able to define a class. You just have to learn a few simple techniques for using the library components. At the same time, experienced programmers can use the full facilities of OOL whenever necessary. OOE provides the best of both worlds: a simple way to produce application programs using a comprehensive
component library and the full power of a standardized programming language for those with more far-reaching requirements.

All said above about developing GUI applications in OOE:s is valid for developing architectural designs: user-centered design, the design cycle, the skeleton-framework-class-object hierarchical approach, the available framework tools. It is hard to define what's creativity about, but ignoring what OOE:s already has in store is anything but creative. It's reinventing the wheel, ignoring what is readily available. Within an OOE each designer can draw upon and add to what others have done in the form of architectural class hierarchies. If you come across an idea of general utility, make it a class or component and publish it on the Web, for all to use and re-use. If you can be more specific than others, derive your class from someone else's more abstract class. If a composition of features is needed, derive your class from several parents. An architectural style can become a class, or a hierarchy of classes. An individual architect or a group can develop their own style, based on someone else's effort. All sorts of legal codes and technical standards, once put into classes, will be automatically fulfilled in designs that use objects-instantiations of such classes, with obvious increase of design quality. Clearly developing useful classes is creative. And the effort put into transforming the subjective and vague ideas in the designer's brain into the objective structure and intelligence of a class is illuminating. It also enables sharing with others, humans or machines. But it is equally creative finding the best of available classes for a design job, customizing the objects, and turning them into a harmonious whole. And because the Web is becoming an OOE, orchestrating distributed design by a community of networked users, designers, consultants may soon be more creative and productive than the current, disintegrated approach, where each designer and each design is an isolated island.

**Dynamic object-oriented approach: design as a networked game**

The second, radical view of architectural design is based on a whole new way of thinking about computation, where computations are about concurrent interactions with users, networks, and environments. Almost any software program of significance today is composed of concurrent interactions among communities of entities. Today's programmer can never be ignorant of the context in which a program will run. There are always many things going on, inside your program and around it. That means you need to know how to think concurrently. The questions become: What are the services my system provides? Who are the entities that make up the community that is my system? How do these entities interact to provide those services? In the old system, computation is a process of sequencing steps, there is a single thread of control and you own it, and all you have to do as a programmer is tell the computer what to do next. That's not reality. A computer is a system of continuously, simultaneously interacting parts, you can't really isolate the pieces. Today, user actions often affect the computation's execution. And increasingly, computations have pieces that run simultaneously. The Java language presumes these types of computations at the most fundamental level. In designing the language, the Java developers were aware that computation is about constituting communities of interacting entities. The fact that threads are a part of Java is evidence of that. The fact that GUls were built into Java is evidence. The fact that networking was built in is a natural
consequence of that thinking. This isn't surprising because Java technology was originally designed for set-top boxes, which are embedded systems that have to interact simultaneously with users and televisions and networks. They have to be able to handle a lot of things going on, if not concurrently, at least conceptually concurrently. It's not at all surprising that the Java language was the right language for programming the Web. Because in building a programming language that would fit the needs of embedded systems, the people at Sun were building something that anticipated that things would be coupled together concurrently rather than sequentially, and that the world was full of an ever-expanding community of entities, each of which might be communities within themselves. Java is a simple, object-oriented, network-savvy, interpreted, robust, secure, architecture neutral, portable, high-performance, multithreaded, dynamic language. But we are still entrenched in an outdated computational model: a single-thread-of-control static problem-solving view of the role of the computer program, and computation as calculation, which does not correspond to our computing environments. Instead, we should conceptualize computation with a model of computer programs as simultaneous ongoing entities embedded in and interacting with a dynamic environment: computation as interaction, computation as it occurs in spreadsheets and video games, web applications and robots. Perhaps the most fundamental idea in modern computer science is that of interactive processes. Computation is embedded in a (physical or virtual) world; its role is to interact with that world to produce desired behavior. While von Neumann serial programming has it that computation-as-calculation uses inputs at the beginning to produce outputs at the end, computation-as-interaction treats inputs as things that are monitored and outputs as actions that are taken over the lifetime of an ongoing process. Current practice changes the fundamental vocabulary of computation: not only are functions replaced by interaction patterns, but these interaction patterns take place concurrently and asynchronously. Programming no longer (necessarily) involves designing the flow of control in a system; instead, it is fundamentally about constituting a community of autonomously interacting entities, deciding what goes inside and what goes between them. Systems today are increasingly difficult to describe in the old paradigm. Networks, distributed computing, and concurrency are integral parts of the computational world. And languages such as Java force us to confront these issues. In the new vision, accounting for the role of the user becomes straightforward: the user is another member of the community of interacting processes that together constitute our computation. A program of this type is judged by the set of services or behaviors it provides. This description characterizes robots and software agents; it is descriptive of operating systems and network services; it fits video games and spreadsheets and modern word processing programs, as well as the controllers for nuclear power plants and automotive cruise controls. In modern computational systems, much of the interesting behavior is generated not by individual components per se, but by the interactions among these components. New approaches to computation are needed at many levels, from theoretical foundations to design methodologies. This is less a shift in the systems that we build and more an upgrading of our understanding of these systems. Every Java program with a graphical user interface is inherently concurrent. We must get rid of our sequentialist illusions and live from the very beginning in a potentially concurrent, distributed, interactive, embedded environment. The atomic unit of the new vocabulary is an infinite loop that senses and reacts,
handles service requests in turn, or behaves. This approach to computation has the potential to build bridges with neighboring and less obviously related disciplines. The community model of computation is similar to foundational concepts in organizational science and other social sciences. Reconceptualized, the truth of computational practice is much closer to complex systems engineering.

Taking this model of computation as a model for architectural design is only a matter of time. All operating systems of significance work like this, even those inside modest desktop PCs. The Internet and the Web work this way. We find here a general conceptual framework and a living, all embracing, omnipresent, ready 24 hours a day environment. All arrangements of users (clients), designers, consultants, hardware and software are supported here and all modes of their interaction are enabled. Everything and everybody is just an object in a community of interacting objects. Cybernetics as the theory of/for design (Glanville 1997) can be put here into practice. The fundamental concepts of cybernetics are supported in a natural way. There is feedback between objects-actors enabling them correction of their state and behavior and evolution by trial and error towards a common goal. Control is distributed between the actors and works in two directions between any pair of objects. Humans (designers, users) can work personally, on-line with each other and with software objects, or can be represented in a computation through tireless software agents. Actually, humans are, at one extreme, too slow to control a computation in real-time. At the other extreme, they are to impatient to wait for the result of a lengthy computation, the more so that it may be not at all clear what kind of result to expect. Furthermore, software agents can be anywhere, anytime, and there can be a host of them. They can check each and every aspect of an evolving design, real-time. They can have and use all senses (touch, smell, hear, feel the temperature, not just see), unlike a human designer (detached classical observer) observing a walk- or even fly-through. Thus software agents acting on behalf of human actors seem a viable alternative to personal involvement. The intellectual effort spent on trying to define such an agent (or many of them for different aspects of design) is an invaluable added value, and occasion to learn. The variety of such systems is enormous, compared to what we have today, and so is the potential for emergent, surprising forms.

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ABSTRACT
The Modern Movement in Architecture put forward industrialization, mass production and standardization among its most important banners. At the end of the century those principles are partially applied. However, the overwhelming growing of exchanges and the purchase of artifacts coming form all over the world to be assembled in order to create new artifacts, determines that in the short span, a world wide standardization becomes unavoidable. Designers should be aware about this imminent issue. Working with standard objects means modular thinking. If modules are conceived as sort of constraining entities framing the mind, creative thinking is facing a gloomy prospect. Creativity and freedom seem to be jeopardized by ready made objects. In fact, from the beginning of design as a form-giving activity it exists a dialectic between creativity and feasibility. It is not surprising since designing is essentially the transformation of ideas into real world objects. Nonetheless, the increasing standardization and the indispensable use of computers are exasperating that dialectics. In this paper is argued that if the characteristics of modular procedures are used in the early stage of the design process to prompt the form for further adjustment, creative thinking is released from excessive awareness about dimensional constraints. The first part of the paper is devoted to the description of the contextual trends that make modular thinking relevant. In the second part some propositions about the use of computer systems to generate “modular freedom” are exposed together with examples illustrating the proposed process.
CREATIVITY AND MODULARITY IN ARCHITECTURE

A word on the globalized world
Globalization trends go in the sense of inclusion embracing every object and every action performed in the world. In so doing, particular things are confused with the general case. Details are ignored or chopped out in order to easily packing together objects and procedures. This generalization trend has its counterpart in an equally strong specialization trend. Both trends grow symmetrically feeding each other in a recurrent manner. The urgent need to generalize is a consequence of the fantastic development of the multiple ways the world is explored. Every discipline has exploded into different branches each one going to its own. This exuberant growing make the ones overlap on the others. Where is nowadays the frontier between Medicine and Engineering? Biology has become a sort of mechanics of compounds and surgery is a machine dependent activity. At its turn Engineering dissolves itself in number of particular technologies being strongly computer dependent.

At this point the branches prevent to see the forest and the forest is taken for the branches. It is a somewhat tropical forest where interwoven branches have taken the place of trees; stems are ignored not to speak about roots. In the global mood, generalization is in fact a kind of simplification because the loss of referential points conceals the path from the particular to the general and viceversa. In order to cope with the bulk of particular objects, which have lost their original stem, parcels of adjacent objects are cut out from the whole following rather practical purposes. Thus “new” disciplines are created. These are composite bodies of knowledge owing their existence to the clustering of particular procedures coming from the “old” disciplines. Clearly, every new parcel is a package of knowledge having no other structure than just occasional connections. So what appears to be a generalization process is a cutting down operation to ease the packing operation.

This state of affairs leads to standardize objects (ideal or material). A standard object is one whose particular characteristics have been reduced as much as possible aiming to make it compatible with other objects. This means that every part of standardized system although sharply specialized, must resign its profile surrendering to the rule of coexistence. This is true for objects as well as for activities, procedures and even persons. As things and persons are cut down to fit into the general cut down parcels they are separated from their stems and roots: they are just leaves of the global foliage. People inhabiting globalized areas accomplish the same ritual activities moving through standardized environments. Office buildings, high rise buildings, factories, hotels, shopping centres, stations and airports, etc, are altogether the same, no matter which country they could be. These are what the French anthropologist Marc Auge (1998) calls the “no-place” buildings because they have no signs of appertainance but just symbols of a common global trunk. Images, procedures, instructions and recipes travel easily trough the world ruling clothes and food (Christian Dior, Mc Donald’s, Domino’s Pizza…) as well as prescribed rituals.
Let us finish the present section with a good example of the way things are going at the moment. Consider this paper itself. It has been written following precise prescriptions; it has been sent to participate in an academic/professional ritual; it deals with “old/new” subjects contained in a quite new created parcel whose label is “Architectural Design/Computers/Creativity”; it has the usual “conference standard” format so as to be packed together with other standardized papers; probably the resulting proceedings will be identified by an ISBN number, finally, authors and organizers will be happy if a Library Congress Catalog Number is obtained.

A word on standardization
Of course the idea of standardization is a quite old one. The Industrial Revolution of the nineteenth century accelerated the movement towards unification of systems of weights and measures. However, standards were the matter of the separate industrial or administrative fields each one obeying to the particularities of the objects they dealt with. It was only around the second war period that in many countries studies aiming to establish general standards started through the creation of national agencies. The result was a constellation of overlapping norms. Being firmly anchored on national industries they have an inertial weight making difficult the integration process. Despite this, the needs of a globalized market lead fatefully to generalized systems. Therefore design tasks will be increasingly devoted to the combination of standard objects following precise prescriptions.

In which concerns architectural design the Modern Movement promises a fantastic development of professional activity through industrialization and mass production, standardization was the axial force organizing design and production. Some more recent movements have taken the same banners insisting on industrial assembled components. Although it seemed to go in the right direction results have been deceivingly restricted to some local cases. Probably the rationale for this can be found in the very nature of Architecture which is reluctant to accept exogenous compromises.

Meanwhile the building industry has been going ahead riding on new technologies, just in the same way as during the second half of the nineteenth century when architects were surpassed by the evolution of the surrounding world.

A word on modules and modularity
In regard to Architecture, even if a reduced standard system is attempted, number of entities ought to be combined taking into account their respective nature in connection with the function they accomplish into the whole. From design tasks to construction tasks interlocked aspects need to be considered. All these are ultimately contained by spatial forms. When spatial forms are integrated in a standardized system they become modules. These result from related geometrical characteristics (shapes) and co-ordinated dimensions (measures).
It is worth noting that in architecture the concept of module has many meanings depending on the context it is used. The word module can be used to signify some abstract numerical entity as well as some material object. At its origin module was the size of the diameter or the semidiameter of the base of a column, taken as a unit of measure by which the proportions of the others parts of classical buildings were regulated. In this sense a module is referred to as a particular measure governing the composition of a particular building. It does not express precise dimensional data, even though that kind of module became a sort of universal ratio (institutionalized by Vitruvius). When a module is defined by a size (or sizes) intended to be repeated in some co-ordinated manner it represents a unit of a particular modular system. Moreover, if the module has a shape determined by relations between parts and its corresponding sizes it becomes an element, which under certain rules can tesselate the plane or the tridimensional space. Finally, when shapes and sizes have their origin in some building component (as tiles or iron sheets to cover roofs) it conveys the idea of materiality of the thing even if the module itself remains an abstract entity.

This is not the place to go into detail about modules and their co-ordination which is a subject well developed elsewhere (see for instance, B. Martin (1965), L.March y P. Steadman (1971), Caporioni et al. (1971)). For the present purpose it is sufficient to remark that from old ages the idea of modularity has been at the core of architectural thinking. It has evolved becoming nowadays an indispensable help when mass production is envisaged. As it has been argued in the foregoing discussion, standardization and its corresponding modular counterpart will take an increasing protagonism in the globalized scene. It concerns not only industrial production but also corresponds with the need of hasty multiplication. Standard objects can be reproduced individually far from industrial chains. At present number of commercial firms spread all over the world their standard buildings composed of modular pieces to be adapted to the particularities of local sites. Taxes and transportation costs are saved because once the modular layout is ready local contractors can materialize it. Thus the image of standard buildings and hence their implied modularity is rather a common stuff in the urban scene. We will come back on this point later. Now it may be sufficient to stress the fact that a worldwide organized manner of designing is taking the pass of the up to now usual design techniques. To be efficient it needs standard forms, fixed sizes and quick communication. Modular design and Internet are there to provide with.

A word on creativity in architectural design
For a start it is convenient to define which kind of creativity we are referring to. In our Communication Era the meaning of many words has been fading away. They are employed for too much purpose and in too much occasions. Among them the concept of “creativity” has become particularly ubiquitous. It covers a large range from the creativeness shown by children drawings to the inventiveness of scientific research findings. Nowadays a creative person is someone whose ideas are little more than trivial. On the other hand, in terms of Arthur Koestler definition (1964), creation is to join systems, which were formerly separated. If this sense is retained only Isaac Newton’s or Vicent Van Gogh’s can be defined as creative work.
It is not our purpose to go into the semantics of the word "creativity" but to establish a reasonably accurate meaning to be applied to architectural design tasks. For instance, the Information Theory says that a message conveys information only when something of new is communicated. The more unexpected is that information the more information the message conveys. If something is awaited it means that its existence is already known. In the same way the creative act has the property of being surprising. Known facts are waited to come or to occur in determined contexts. Creative propositions modify the expectancy about what might come up. In these terms only unexpected artistic or scientific work is truly creative. A creation gives new insights and new definitions. Once a new definition is built up, number of different descriptions around the defined characteristics can be done. Descriptions depend on and proceed from previously stated definitions. As the core of a creation is a new definition, new descriptions are only variations on the same theme.

With all this said it is time to come to creativity in the special case of architectural design. But before go further we must consider, to some small extend at least, the relations between architecture and design. Let us propose that designing is to describe previously defined ideas. The act of creation is achieved with the definition of an idea. At its turn, the definition is the delimitation of a part of the world where the defined idea is isolated to stand up in front of the rest of the ideas. That delimitation is done within the limits of the idea of architecture that the architect has in mind. Therefore defining an architectural object is an act of pure conception, which proceeds any description. Only when the definition is given the design tasks can start (i.e. the description of the defined idea).

As a description proceeds in terms of some understandable combination of signs, the role of design is to make feasible in architectural terms the things that an idea proposes in more or less general terms. Notionally speaking, a description is a sort of conventional representation. So as numbers represents mathematical entities, so architectural ideas are represented by material objects put together during the process which begin with the designing description and ends with the building materialization.

If the foregoing argument is accepted it should be clear already that the design tasks themselves are not creative because they are subaltern to architectural ideas. Moreover, if that notion is applied in watching the nowadays architectural scene, it may be readily visualized that new architectural definitions are rare, whereas designing descriptions spinning around the same theme make a bulk. In terms of Information Theory these descriptions are a lot of messages referring to the same information. Often some of them are surprising messages. In that respect it is important to realize that a message may be surprising owing to the unexpected form of the message. Thus new descriptions can appear as new definitions. It is a usual advertising technique to draw attention on old known items by suddenly changing the manner they are presented. In this case the novelty comes from the manipulation of the form of the message. They can be looked at as decorative descriptions of known definitions. These might be creative in the way that they manage to represent the signs of architecture, often abusing these signs, either
exaggerating some features (bunches of pipes and gigantic trusses) or reducing at its minimum all features or labouring ad infinitum geometrical arrangements.

We are not going to say which kind of creativeness fits architectural design. However, we suggest that there is a mayor difference between those that give definitions and those who describe them. The former are the big architects, the late the vast host of designers. In view of this, we should be on our guard and consider more critically the demand of creativity in almost every designing act. Creativity is a burden put on the architect's shoulders from the beginning of their education. After all, the compulsive search of creativity and uniqueness, together with sheer competition are shadows projected on the profession from the times of the "Grand Prix de Rome".

About modular thinking
In the preceding sections we have touched to various themes. All of them are concerned with the use of modular systems to design. As already said, we are not introducing something of new neither some special way to prompt creativity. The above arguments were directed to pay more attention to what it might be called "modular thinking". Following the globalization wave we are accustomed to think in terms of combining miscellaneous pieces. Of course, Architecture is not spared from this growing trend. Some architects speak on their work as "assembled fragments" reflecting a somewhat nostalgic resignation about a lost order. On the other way round, working with modules is not intended as a gathering fragments operation. There is an established order into which every piece (modular) is inserted following established rules. It hardly needs saying that, in creative grounds, that order makes its strength but also its weakness.

Now let us examine the consequences on the everyday design tasks. First of all we assume that professional work can be divided barely in two classes. The one is constituted by the work directed to very special issues. It needs of outstanding features, as is the case for institutional edifices, large splendid houses and so on (some authors have called that kind of work "The architecture for the Princeps"). Obviously the number of designers in charge is very small and their aim is precisely to avoid modules and standardization. The other kind of works makes almost the whole of the buildings constructed in the world. As it is well known, architects design a reduced part of them. This special part of the general designing work is going to be the more and more modular since it is constituted by a good deal of massive building.

When in the 1930's A. F. Bemis proposed the adoption of modules to be applied to prefabricated houses he was thinking mainly about the industrial process. Bemis wrote his "The Evolving house" (1936) about modular co-ordination. He said almost nothing about modular design itself. A short time after Bukminster Fuller proposed his Dimaxion House, but although he actually designed a dwelling system his chief purpose was to convert the, at that time idle war industry into a peaceful domestic industry (see R. W. Marks (1960) and S. Rosen (1969)). At the beginning modular thinking referred mainly to sizes and the way as these can be co-ordinate. More often than not it was a matter of numbers and design issues were seen as an aside result.
Meanwhile Le Corbusier proposed the Modulor as an attempt to convert into numbers his humanistic view of architecture. He started from human needs to go to measures. According him human measures were the vehicle to draw organic life into the inorganic fabric of buildings. Probably he was feeling that the opposition to standardization could be overcome introducing an aesthetic order in the somewhat uncompromised modular objects.

Frequently objects made up of modules are considered of minor value because their forms betray a mass production origin. Repeated parts proclaim that the resulting arrangement can be repeated again and again. Repetitions are seen as tedious and lifeless. Curiously enough, organic life is highly modular. Life is in fact a repetition system made up of surprisingly few basic elements. The method of combination is the key to understand its enormous diversity. Consider a mass of living beings: a forest or a herd of cattle. They are monotonous as tiles or bricks if observed in isolated patterns. But if some distance is taken so as to look at the outline surrounding the mass of undifferentiated things, it can be seen that it performs an ever-changing profile.

A final example
In the above discussion we have suggested that design tasks must be preceded by actually new definitions to produce creative work. Fresh information makes genuine messages. But the same information can be presented in different ways. Lest us end this paper proposing that modular thinking offers the possibility of organizing messages far from fastidious repetitions. Beside this it should be remembered that computer systems are also modular systems. Furthermore, computer processes are mainly combinatorial operations. At its turn architectural design operations proceed combining and selecting the pieces of information supplied by the architect’s definitions. From that we conclude that Computer Aided Design is a convenience marriage. In spite of this CAD systems remain mostly drawing aids rather than properly speaking design aids. The following example is intended just to hint at some possibilities in developing computer systems that could help the designer in his design operations.

Figures 1 to 8 illustrate the work of a computer program conceived to design modular forms. Is helps the designer to trace shapes whose outline (closed or open) is always modulated by one or many determined measures. It draws straight or curved lines. The late are actually polygonal lines whose segments correspond to the given module. It is also possible to choose among different types of polygonals (armonic, precise, centered and so on). This procedure liberates the designer from excessive awareness about geometrical conditions and dimensional constraints because these are calculated by built in routines of the program. The Figure 1 shows a modular layout and the Figure 2 shows the boundaries of a set of buildings inscribed on the modular basis. If the pattern shown by the example were traced by hand it could be a quite complicated operation. Using the computer program the designer avoids to be involved in a painstaking modular co–ordination. Beside this he or she can examine each step and come back if necessary.
The design of modular tridimensional components can be done through the same program. Figure 4 shows some of the pieces used in the composition of the set of buildings illustrated in remaining Figures. The procedure of insertion of components is straightforward and can be performed in 3D (see Figure 3). Figures 5 to 8 show some views of the different possibilities of assemblage.
To conclude this paper let us summarize the main arguments:

• Architectural design is not being spared from the standardization wave.
• Standard objects can be combined if they have suitable modular forms. The success of modular arrangements depends on the modular system rather than on the particularities of the components. In the same manner the beauty and fitness of modular objects depends on the way the modules are combined.
• Computers are powerful devices able to perform complex combinations. However CAD systems pay few attention to modular problems and their management.
• Modular thinking prompts the mind to deal with standard objects. It does not guarantee creativity but helps to adapt the design procedures to the piecemeal events that characterize the global scene.

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EVOCATION AND SERENDIPITY IN A CYBERREAL WORLD

AUTHORS
Martijn Stellingwerff
MEDIA, Faculty of Architecture
Delft University of Technology
Berlageweg 1
2628 CR Delft
The Netherlands
m.c.stellingwerff@bk.tudelft.nl

ABSTRACT
Adding two apples to three oranges is not possible in a purely computational way. It takes creativity to see that you have got five pieces of … fruit. Computation implies exact solutions while creativity is needed when there is an arbitrary gap or bias in a given situation. This paper is about the explicit introduction of gaps and biases in a visually simulated world. The computer is treated as a medium in which reference information from a virtual city model is confronted with sketch objects. The juxtaposition of referential information and sketch information delivers images that can evoke new ideas. The serendipity (gift to pick up ideas) of the designer transforms the given capricious cyber-real world into useful ideas and inventions. This process is supposed to trigger creativity for urban and architectural design.
EVOCATION AND SERENDIPITY IN A CYBERREAL WORLD

Introduction

The conference theme - ‘Creativity & Computers’ - can be split up into (at least) three totally different questions:
How can computers be used to facilitate creativity?
How can computers be used creatively?
How can computers be creative?

In our Media research at the Faculty of Architecture, we focus on the first and the second question and set the third question aside. This is not remarkable because we consider the computer as an instrument and a medium in relation to an intelligent designer. We do not see the computer itself as a topic of our research and we certainly do not use the computer as a machine for Creative Artificial Intelligence.

We cannot answer the third question because computers are creatively programmed machines which can only re-create according to their algorithms. It takes creativity to design a computer algorithm, not to execute it. Artificial Intelligence (AI), although very useful in certain applications, is based on nothing but (more or less) complex Pavlov reactions. AI produces expected results based on learned actions in known, recognised or similar situations. In contrast to AI, creativity produces new and unexpected results based on inspiration, mistakes and serendipity in seemingly not solvable problems and new situations. Creativity is needed when a problem cannot be solved by mere computation. Many problems that ask for a creative solution consist of two or more incompatible parts that just do not fit. As in jokes, humans understand the problem of incompatibility and they react with laughter or creative solutions. Computer programs can produce jokes, but they will never laugh meaningfully. And it is exactly the same with creativity; computers can produce and represent problems, but they cannot solve the problems creatively. Therefore, let us use computers for what they excel in: gathering, manipulating and representing information.

1 ‘We cannot imagine humor without imagining some unexpected event.’ In jokes ‘thoughts are not presupposed with a current context or situation.’ [Boelen, 1998].

2 In 1997 Donald Schön was a visiting professor at the Delft University of Technology, during one week Schön gave his last lectures and exercises to a group of Ph.D. students in Architecture and Design Research. I feel privileged that I could speak with him and feel optimistic after he agreed so intense with my thoughts about media and their evocative role in design. Two years later I found the following text, which again confirms and reassures my thoughts about AI and Design Media. [Schön, Donald A. and Wiggins, G. 1992]: ‘Some of the best minds engaged in research on design computation have focused on the problem of developing computational representations of design knowledge - in effect, on the problem of building machines that design.”. When we think of designing, however, as a conversation with materials conducted in the medium of drawing and crucially dependant on seeing, we are bound to attend to processes that computers are unable - at least presently unable - to reproduce: the perception of figures or gestalts, the appreciation of qualities, the recognition of unintended consequences of moves.
It does not follow from this that computers can have no significant use as design assistants. What is suggested, on the contrary, is that research should focus on computer environments
Still we argue that computers can be helpful in creative processes; primary as a tool, preferably as an instrument but professionally as a medium. The instrumental qualities of computers turn up when a toolbox is refined for a certain task in a specific domain (e.g. detailing in architectural design). An instrument can be used to make precise choices and refinements based on clearly represented design propositions [Breen and Stellingwerff, 1996]. The computer as a medium enhances insights and diversifies the designer’s point of view based on imaginative representations of previously expressed design ideas and gathered referential information.

At this occasion, in which computers and creativity are assigned as the main theme of the 2nd AVOCAAD conference, I would like to develop a ‘creative media theory’ which draws from findings in design protocol analyses and papers of other researchers about design and creativity. First, in a side-step (or even a ‘pas de plier’) to ‘artificial intelligence’, Pavlov’s conditioning processes are reviewed. Then in a next step a similar set of processes for innovation, creativity and ‘media-content-conditioning’ is presented. Secondly the term ‘situattedness’ is clarified and different possibilities to create situatedness as a kind of conditioned-media-content are explored. As an illustrative third step, the juxtaposition of elements is presented as a useful method to produce situatedness in creative urban sketch sessions. All this theoretical fuss about creativity, media and computation should provide more insight in the aspects of computers which can guide our creative design processes with evocative and informative information.

From Conditioned Reflexes to Innovation and Creativity

Figure 1 shows the classical conditioning scheme of Pavlov’s experiment with dogs and their reaction to stimuli. Essential here is the combination of two stimulus-events in the dog’s brain. The dog is conditioned for the combination of hearing a tone (e.g. the sound of a bell) and tasting food in the mouth. After training this results in salivation of the dog when it hears the tone again, even if there is no food provided. The dog re-acts on an acting environment in which sounds and food occur.

| before training : | S (food in mouth) ➔ UR (salivation) | ➔ no relevant response |
| S (tone) | training : | S (tone) + S (food in mouth) |
| after training : | S (tone) ➔ CR (salivation) |

S = stimulus | UR = unconditioned reaction / reflex | CR = conditioned reaction / reflex

Figure 1.

If the dog is out of the laboratory it can live in a rich environment with many stimuli. The dog can choose what to do and how to act. Many different actions that enhance the designer’s capacity to capture, store, manipulate, manage and reflect on what he sees.’

are rewarded and thus a rich behavioural complexity is built inside the dog’s brain. I assume this complexity of classical conditioning is what we can see in most of the current AI applications. It is just the amount of conditioned reactions that astonishes and makes people put the ‘intelligence-label’ on it.

The Pavlov experiment is investigating training and animal reactions. The opposite is action-research and the exploration of human volition. Figure 2 shows a scheme in which an attempt is made to introduce real 3 ‘conditioned stimuli’ in a design media environment.

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3 Pavlov’s use of the term ‘conditioned stimuli’ (CS) bothers the fact that it is just the dog that gets conditioned and not the food or the bell. I re-use the term to explain how media content can be refined in order to inform and evoke.
How can we condition our design media in order to be creative and invent things? Personally I would answer: ‘at least DO something!’. When a design problem seems irresolvable you should just start somewhere and try things out. The medium, whether it is cardboard for a scale-model, pen and paper or some kind of computer program, will bring you somewhere…(5) The message of the medium will get conditioned for the problem which you worry over. The scale-model, the drawing or the computer model becomes more precise and represents the design problem at hand. Eventually the medium provides insight, clues and evocation. Then you have to be alert and pick up the ideas, and when you have found what you did not ever expect to find, you can call that your serendipity⁴ or ‘generated inspiration’ (6).

Situatedness and Unexpected Discovery
Design Media and media-content can be valued for their ability to inform and their ability to evoke. Thus we can speak of the information value and the evocation value of design media. The properties for information value can be e.g. the amount of data, the reliability and the accuracy. Evocation value is much more difficult to define. Evocation is the ability of media, media content or situations to bring up ideas in someone’s mind. So, evocation value can be anything, as long as it is picked up by someone and as long as it is related to problems that can be solved with it. Evocation is dependant to the serendipity of a designer. Evocation and serendipity will more likely occur if a designer is in an active dialogue with the design-media. Skills, attentiveness and interaction are essential in a good use of design-media. This shows the importance of behavioural protocol analyses in design-media-research.

If media provide such kinds of information that a designer gets enough evocative and informative clues to tackle a demanding design problem, one could speak of ‘situatedness’. The term ‘situatedness’, introduced by Clancey [Clancey 1997] is described as ‘where you are when you do what you do matters’. Most people have experienced that they suddenly got a nice and good idea and immediately afterwards forget the idea because they were distracted by something or someone. When they go back to the place where they first got their idea, they go back to that place in order to remember. This is their appeal to situatedness.

By breaking Clancey’s definition of situatedness in parts, links can be made between these parts and aspects of design media and the application of design media.

‘- where you are -’ is the actual surrounding of reality and visualised or simulated aspects of reality. In computer Virtual Reality applications (VR) we can call this surrounding a ‘cyber-real world’, because it is partially representing reality and partially result of computed phenomena. Cyber-Reality is ‘defining the area in which our creative activities take place’ [Asanowicz 1998]. Where you are is very important for creative processes. The virtual environment and the real environment provide what can be called ‘the stimuli in design’. If these stimuli are conditioned for giving the right

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⁴ Serendipity is the ability of someone to find or remark something which he or she was not especially looking for.
information and evocation for a certain problem, there is a good starting point for a designer to find appropriate design solutions. ‘when you do’ is referring to an interactive process, doing is acting and reacting to the media content in a sketchy or refining way. Most important is ‘that you do’, for if you do not, nothing happens … ‘what you do’ is referring to specific acts of designers. Someone who is very skilled in using media is most likely and possibly consequently a creative person as well. Knowing what you can get from a medium, knowing how to draw and manipulate images is the way to transform air castles into real architecture. The ‘where, when and what’ of ‘acting in situatedness’ make the role of media in design very clear. Whenever we are inspired or persistent in our design activities, media can provide a more or less conditioned environment with which we can interact.

Situatedness in reality or situatedness which is represented by media can evoke. People can be serendipitous and pick up the evocation. They can do ‘unexpected discoveries’ [Schön and Wiggins, 1992]. This theme of ‘doing unexpected discoveries’ is described in a protocol analyse report. Schön and Wiggins summarise the research as follows: ‘We shall describe architectural designing as a kind of experimentation that consists in reflective ‘conversation’ with the materials of a design situation. A designer sees, moves and sees again. Working in some visual medium - drawing, in our examples - the designer sees what is ‘there’ in some representation of a site, draws in relation to it, and sees what has been drawn, thereby informing further designing.’ In this description of their research, two main aspects of situatedness come together: some representation of a site and a drawing in relation to it. The designer starts a reflective conversation. The site, or context of the design, acts as referential information. The designer sees the site and picks up exactly what aspects are needed for the further designing. Then a movement is mentioned. This can be a shift in point of view, or a ‘re-framing’ of the design problem. Moving and seeing again gives new insight. When the first sketch strokes are jotted down, immediately another new image occurs. The relation of the design in its context is ‘reflected’ by the medium. At that moment it already becomes difficult for the observer (protocol analyst) to be aware of all design steps … the reflective conversation is on its way.

Parataxis to Evoke Creativity
The above mentioned ‘some representation of a site’ and ‘a drawing in relation to it’ are actually the two essential aspects of my Ph.D. research. They form very important primary information in almost any architectural design process. My research focuses on questions like: ‘what kind of representations’, ‘of what parts of a site’ and ‘which relations to a site are essential in the perception of the designer’ and ‘which aspects are forgotten’. After many pilot studies, workshops and little tests with the Virtual Reality Modeling Language (VRML), I found out that situatedness can be provided if you make a medium (computer program plus the content) that combines ‘representations of the site’, ‘3d sketch matter’, and all kinds of ‘evocative objects’. Ideal prescriptions for these three ingredients are not yet ready.
'Creativity in design by using prototypes can be performed by processes of combination, mutation, analogy and by the use of first principles' [Rosenmann and Gero, 1993]. I think these processes are not bound to just prototypes. They can also be found in less definite aspects such as forms, directions or colours. All kinds of combinations, mutations, analogy and first principles can be used in creative processes. As a, albeit arbitrary, conclusion to this paper, I would just like to mention the imaginative power of combination, which I partially try to explore in my research.

The concept of combination in sketches and drawings is very much accepted in architectural design practise. By drawing on semi-transparent paper and by using a layer system in CAAD, the juxtaposition of different information gives a combined insight. When a sketch layer is placed over a drawing of a site, the above described situatedness may occur. In VRML, these juxtapositions can be made in three dimensions. In my research, I combine (1) the information of the site, (2) the evocation of different evocative objects with algorithmic behaviours or constrains and (3) sketch-matter which can be used for jotting down ideas in reflective conversation with the medium. The 3D layers can consist of semi-transparent images, photos, texturemaps, 3d geometry, text, sections and maps. The possible and adaptable combinations should give insight, evocation, gaps and problems in order to give the designer’s creativity a chance to react.

Finally I want to mention the phenomenon of parataxis in linguistics. The parataxis stands for two unrelated words which get a new meaning when they are combined and joined together. For example: “fire-ball” which can nowadays be understood as the sun. As a computer can make all kinds of jokes, it can also make parataxis’s on a word level, in images or in Virtual Reality. The parataxis can be seen as very evocative. Still it is not creative. Creativity comes in when the computer-user sees these images and makes interpretations. Serendipity helps in this process to get unexpected ideas. It would have been serendipity when the electric lamp was invented based on the combination of the two words ‘fire-ball’.

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‘Parataxis: Kennings. The kenning is one example of a formula in Old English poetry that helps the listener visualize the spoken text. A kenning is a phrase used in place of a simple word. It consists of two words related to the object but not necessarily to each other. Thus world-candle stands for sun, gold-friend for lord, whale-road for sea, and fire-lizard for dragon. A more metaphorical phrase such as “the candle of the world” would not hold up under Old English metrical standards. The kenning serves to slow down speech that would otherwise be too fleeting and to create a powerful, dense image. In this way a kenning might serve like a large picture on a web page that takes a long time to appear on screen.’
FORMULATING
A COMPUTER-AIDED ARCHITECTURAL DESIGN (CAAD)
PROGRAM MODEL
IN DISTANCE EDUCATION (DE) AT OPEN UNIVERSITIES (OU)

AUTHORS
Ra'Ed QaQish
Khaled Tarazi
School of Architecture
P.O.Box 961 343
Amman- Jordan

ABSTRACT
This paper reports on a project that aims to formulate a CAAD program model in Distance Education (Learning/Teaching) framework, to be applied and implemented in future settings at Open Universities worldwide. The methodology used to establish the CAAD program model consisted of a worldwide literature review on the subject of Distance Education and Open Universities. It also involved an assessment of the methods and means used in the delivery of materials to students enrolled at Open Universities, together with an analysis of the current program of study and subject related courses. The methods of this investigation consisted of a comparative analysis between the existing models of teaching process at Open Universities and how it relates to CAAD in architecture schools. The study endeavored to examine several issues that were found to be key factors in any Open University system, namely: the methods of study, program of study, student type/body, academic/degree requirements, and residency/academic calendars. While attempting to establish a conceptual CAAD program model, this study investigated several questions concerning the efficiency of CAAD teaching in Distance Education. One of the study objectives was to determine which factors were mostly needed to effectively integrate CAAD in DE as a new program in Open Universities. In addition, how would these factors affect the design of CAAD courses in OU systems as a new DE program area? And what structural elements would be most affected by these factors? Another objective of this
study was to determine to what extent the new CAAD program model in tandem with staff, learning environment, and administered materials would be effective in generating supplementary strategies in the virtual design studio. A third objective was to evaluate the personal computer station as an alternative design studio space in future settings of schools of architecture. Consequently, the principle objective of this study was to develop and establish a CAAD program model to be adopted by Open Universities as a new subject area in DE. Mainly, the study attempted to locate the areas where CAAD teaching excels in the context of virtual design studio of OU system.
FORMULATING A COMPUTER-AIDED ARCHITECTURAL DESIGN (CAAD) PROGRAM MODEL IN DISTANCE EDUCATION (DE) AT OPEN UNIVERSITIES (OU):
A STUDY INTO AN EFFECTIVE INTEGRATION OF CAAD INTO DISTANCE EDUCATION.

1. Introduction
Distance learning programs have multiplied to an unsubstantial extent over the past ten years. Nevertheless, despite its intense adaptation in academe, distance learning remains remarkably controversial. Educators and scholars have been asking many questions about distance education some of which are essentials and require some answers, e.g. will distance learning be able to refine and enhance the conventional/traditional educational endeavour, or will it atomise the educational establishment to an uncertain extremity? (Aoki and Pogroszewski 1998)

It is evident that several conventional universities and colleges have been compelled to embrace distance education because of the students' social and demographic changes. For the most part, this change is due to students' access to efficient and relevant information. Furthermore, students are demanding educational institutions to apply efficient information access resources to theoretical programs and courses. Such resources are adapted in computer-based instruction and asynchronous learning networks. These necessities are forming the “virtual campus” which many institutions have disregarded, or simply are not aware of the magnitude of this new tool. (Stenerson 1998)

But, what does the term distance education/learning signify? The scope of definitions spread from assigning an instructor to a group or individual students, particular distance or location from the main campus, to accommodating all instruction and communication via the WWW, or using the TV as another medium of transmitting information to students. Among these considerations rest various distinct paradigms in different approaches and fashions.

This multiplication of media, which we may label the term "coexistent environment" raises a number of concerns for institutions. A fundamental countenance is the verification of the distant student, which evokes many challenges in connection to the fundamental prerequisites of any higher education institutions' curriculum. Such examples are skill acquisition by students to process information, and how to address its knowledge acquisitions and aptitude. It is then a fundamental task for institutions and mostly architecture schools to acquire a system design so that distance education can be integrated into its educational system as a whole.

In many universities worldwide there has been a number of system models designed to support distance education. However, none has developed a distance education in architecture schools, mainly because each school has a particular approach towards teaching architecture being affected by cultural, social, regional, or even religious factors. Thus, it could be argued that specific system designs must be tailored for the institution to meet the continuous social and demographic changes of student population. Therefore, this paper attempts to design a prototype of a general system model for
architecture application mostly designated to computer aided architectural design (CAAD). 
A CAAD enhanced learning environment has many distinct factors that can enhance the pedagogical effectiveness of CAAD course content at a distance. It could be achieved through various ways and means such as e-mail, compressed video, group support tools, TV programs, and web-based instruction. Using this technology, CAAD learners can still receive instruction similar to what would have been available to them at a conventional environment. A potential problem might exist when designing a CAAD model for distance education is the application of conventional/traditional pedagogical methods into CAAD enhanced environment. Hammer (1990) argues that one cannot "pave over cowpaths" in the redesign of business processes, hence this would accelerate inefficient ways of performing those processes. It could be argued that a similar case might be applied on CAAD distance education. Thus, when designing a distance learning model for CAAD, the full effectiveness that technology can provide to both logistical distance and non distance learning environments cannot be achieved through "force-fitting" traditional learning paradigms into the technologically supported ones. This paper proposes an integrative CAAD model to enhance a CAAD efficient and effective learning environment through distance learning and provide a framework for instructional processes substituting for the geographic distance obstacle.

2. History and Background
Although there are several universities and colleges offering distance learning/education programs for almost ten years now, yet there is a rapidly increasing necessity to offer instruction and services to learners (students) in a virtual environment at their convenience. During the 90's there has been a growing interest in distance learning/education using personal computers and networks systems. Distance learning/education has gone through enormous modification since the introduction of the personal computer and more recently the superiority of the Internet/WWW. It provides a distance student/learner with theoretical/academic assistance via telecommunications media, thus, giving the distance student/learner the same advantages and privileges a conventional/traditional on-campus learner undergo.

Currently, colleges in the Tennessee Board of Regents System deliver distance learning courses fundamentally in four ways. However, two modes dominate: Compressed video transmissions "smart classroom" over telephone lines and videotapes sent to students' homes or placed in local libraries for use or checkout. Nearly all colleges are attempting to enrol in the on-line market, however the growth of on-line courses has been modest. Stenerson 1998 argues that distance learning can embrace many different forms, ranging from mailed printed materials to desktop videoconferencing.

On the other hand, this increased concern and engagement in distance learning/education among universities and colleges may remain to expand. According to Aoki and Pogroszewski 1998, this area is being fuelled by three major factors:
1) Institutions are looking into increasing enrolment by attracting non-resident students; 2) there are growing needs of adult learners to acquire new skills and college credits while overcoming the constraints of time and distance; and 3) the development of new technologies is making the delivery of distance learning courses more attractive.

Yet, during the last ten years, distance education has managed to question historical apprehension of the concept of traditional teaching. Distance education has been in existence for almost one hundred years. Since its beginning, distance education has acquired a disreputable standing, founding an argument with many traditional universities (Stenerson 1998).

Once again the introduction of computer-based instruction helped greatly in advancing distance learning especially with advents of information technology. According to the U.S. Department of Education (1997), as of September 1995, one third of colleges and universities were offering distance courses and another twenty-five percent were planning to implement distance courses within three years. One-half of the institutions were providing courses to students at home.

As the main objective of this study is not on the examination of different delivery CAAD methods, but rather presenting a comprehensive model of online distance education (i.e., the provision of a CAAD learning environment that utilises computer networks to a large extent to advocate distance learning in architecture schools). Thus, the effectiveness of different CAAD educational delivery methods is beyond the scope of this paper.

3. Distance Education Development
The fundamental conception of distance learning/education from its initiation was composed around separating the instructor from the student. Alternatively, extinguishing the basic concept of one-to-one instruction, which most curricula is built upon at present. Initially, as distance learning started, the correspondence course was the most common model of instruction. Since then, there has been an excessive modification in the concept of distance learning/education that compelled many institutions to confront issues of distance education and the new advent they bring.Founded over the technological changes that have occurred in the field of distance education and IT, D. R. Garrison proposed three generations of distance education. The first generation was based on the printed word and delivered by mail. The second generation was piloted by the advancement of broadcast media, television and radio. The third generation of distance education arrived with the advent of IT and computers and their use to deliver instruction materials (Chou and Sun 1996). Since then, students anticipated institutions to deliver courses “on-line”. It is evident that digital information could yield and prevail a forth generation of distance education that would influence the virtual campus in which many institutions have already adopted.

4. Distance Education Terminology

4. 1. Distance Education/Distance Learning.
The terms "distance education" and "distance learning" interchanged for years, yet in principal, they seem to have equivalent meaning and objective. Education embodies a systematic approach which interrelates learning, the institution, and the learning environment. Michael G. Moore and Greg Kearsley 1996, best described distance education as "Distance education is planned learning that normally occurs in a different place from teaching and as a result requires special techniques of course design, special instructional techniques, special methods of communication by electronic and other technology, as well as special organisational and administrative arrangements."

There is an on-going discussion on which term should be used with the pedagogical arguments concentrating in on the words "learning" and "education". However, in the case of architecture, which is the concatenation of this paper, Lewis (1985) differs that the education of architecture is founded over the curriculum comprising of courses, over all program goals, faculty, physical facilities, budgets, management, and students. Principally, the contents of architectural program are generally divided into three broad areas of design, history, and technology. Thus, this paper will be focusing on the need to develop a CAAD distance system, in which the term preferred, and used, will be CAAD distance education.

4.2. Computer-aided learning (CAL):
The term refers specifically to computers as a learning resource or medium. Thus, proposing that CAL is the use of a computer system to augment or supplement a conventional instructional system (QaQish & Hanna 1997).

4.3. Computer-aided Instruction (CAI) and Computer-aided Teaching (CAT):
The two terms are very similar in their meaning and usage; they both have a common goal and objective when applied. These terms mainly refer to the 'drill and practice' and 'tutorial' varieties. Some authors such as Hooper considered CAI as one type of CAL (QaQish & Hanna 1997).

4.4. Computer-management learning (CML):
The term refers to computer management of learners, which involves the aspects of teachers, instructional materials, media and administrative duties in the computer assisted learning events in CAD. The nature of these three essential domains (factors) is manifested and explored throughout their interdependent relationship with the five domains: cognitive, skills, attitude, creativity, and performance (QaQish 1997).

4.5. Group-based and Individual-based learning in CAL:
The nature of the communication in group-based computer learning and by individual study is such that each involves a distinct process. During the computer-aided learning events differences in what is learnt due to variations in how the communication and learning occur are likely to be found. (QaQish & Hanna 1997) When discussing the issue of co-operative, competitive and individualist goal structures, in terms of the group or the individual, Johnson (1988) argues that computer technology furnishes education with several challenges: a) The challenge to prevent isolation and alienation of students when promoting the effective instructional employment of computers.
b) Computer assisted learning institutes fewer interactions with teachers and classmates, thus advocating the assumption that CAI is primarily individualistic.

c) Computer assisted instruction may have an effect on educational practice, since interpersonal interaction is a key influencing factor on instructional effectiveness and classroom climate. As a result, the possible use of computer assisted co-operative or competitive instruction is ignored.

As distance education advances into a third generation, information technology is bound to shape the future of DE and proposes new means and methods to give birth to computer networks that develop the communication channel for delivering instruction. It is evident that the rise of the two terms that are used when discussing computer networks in distance education are computer-mediated communications and computer-based instruction.

A) Computer-mediated communications is a generic term that depicts the command of people to communicate with one another with computers and networks. Prevalent forms of computer-mediated communications are Internet, e-mail, computer conferencing, bulletin boards, and discussion lists.

B) Computer-based instruction is also a generic term meaning student may communicate and exchange information with computer networks, forming a learning environment. Two of the forms of computer-based instruction entails hypertext and hypermedia. Similarities in the pedagogical issues that originate in computer-mediated communications also arise in computer-based instruction. Researchers and scholars maintain that instruction has moved from learning "from" media to learning "with" media (Hannafin et al.1996; Romiszowski and Mason 1996).

C) Asynchronous Learning. According to Hiltz and Wellman (1997) the main focus of an asynchronous learning network is a "teaching and learning environment ... designed for anytime/anyplace use through computer networks." (P.16) Thus, an asynchronous learning network is a model of computer-based instruction, engaging inspection place without the parturition of location and time.

5. CAAD Institutional Responsibility and Involvement
As the CAAD program with distance education is being initiated at colleges and schools of architecture, it is important to recognise different levels of responsibilities schools may have to indulge in. Moore and Kearsley 1996 suggest four levels of distance education scheme. Level one is Distance Learning Programs which is usually administered by self-working individuals who have no system resources. Distance Learning Units is a self-contained unit within a conventional institution where assigned resources and the potential exists for the design of a system. Distance Learning Institution and Distance Learning Consortia levels depict a whole and dedicated institutional "system" for the delivery of distance education.

This paper will poise the need for CAAD system model and curriculum design for the Distance Education Programs and Units in schools of architecture.

6. A New CAAD Theory of Virtual Campus
"Virtual campus" and "Virtual university" are two terms referred to in distance education theory often in relationship to the incorporation of asynchronous learning networks. Talley 1997 argues that institutions will have to support the "distributed learning communities" but also maintain a level of traditional interaction providing the sense of an academic community. The term "virtual" is applied in recollection of the asynchronous population and the distributed learning process.

This paper foresees the virtual campus through virtual design studios suggested in CAAD model (see CAAD model), and will mostly use the term virtual campus in awareness of the significance and multi-dimension of traditional architecture curriculum endeavour. Thus, the virtual campus and the virtual design studio might in fact propose the exclusion of the physical CAAD studio.

7. CAAD Model Design

Many fundamental Architectural education programs prepare their graduates to deal with current issues of theory and practice. However, the current trend in architectural education is to respond more to the newest technology and consequently to CAD, thus delivering more up to date graduates who can deal with current architectural issues in various environmental settings. Though computer training is often provided in architectural programs, architects practising in these substitute environmental settings facing an increasing demand for computer skills (QaQish 1997). Today, even the AIA examination is supported by computers and architects are requested to acquire a good knowledge of computing.

QaQish 1998, argues that the employment of technology into architectural curricula whether in relation to theory or practice has continually been constituted as one of the pressing enigma in architectural education. Moreover, the impotent integration in architecture between architectural science and creative designs has been a scholarly and proficiently significant debatable question. Architectural science instigates subject based on objective line of questioning while creative designs instigates subject based on aesthetic and creativity.

In addition, with the tremendous expansion of architecture information and knowledge, much of the content presented in architecture programs becomes outdated. Remaining current is vital for the architecture profession and for architects on the job. Many schools are aware of this and taking rapid and vast steps to stay current. Subsequently, this may be accomplished through continuing education and pursuing advanced degrees in CAAD and architectural Technology. In light of this argument, architecture schools should consider the distance education in architecture education as an alternative because of the student population social and demographic changes.

Instructional uses of the computer are important and may help to address these issues. Many programs have been developed world-wide offering courses partially or completely via computer mediated communications (CMC) (Hiltz 1995). Other institutions as discussed earlier in this paper have taken CMC a step further, offering classes online that can be taken at a distance. Architectural education is not any where close to move in the direction of distance education. This paper describes a proposal of CAAD model, to manage a virtual studio for a CAAD course.
More than ever, architectural education programs need to introduce or expand basic computer skills/ CAAD through distance education. Providing CAAD distance education increases access to information and advanced degrees. Moreover, it facilitates the CAAD teaching/learning process advocating a new trend in CAAD. This may also enhance job skills and decline anxiety associated with computer use (QaQish & Hanna 1997).

Two notable difficulties may be solved for architectural students as CAAD model is introduced in any new institution as a distance education system: time and distance. For non-traditional student who have full-time positions in architectural firms or other related practices with varied work schedules along with family responsibilities, time and distance may indeed be of importance, and distance education would surely solve this problem. This paper proposes online course as the optimal choice for delivery and among the different strategies that were examined to help minimise the time and distance factors.

8. CAAD Theoretical and Applicable Basis

Investigating the theoretical basis for online education is essential to understand the importance of the concept in distance education. The work of Otto Peters (Moore & Kearsley, 1996), Desmond Keegan (Keegan, 1998), and Michael Moore (Moore & Kearsley, 1996) all showed a great interest in this area. Each offered various degrees of insight into the creation of courses, and the successful behaviours of teachers and learners. Theories provide direction and guidance for structuring professional architectural practice, education, and research. Teymur (1993) suggests that the controversial issue of whether to classify architecture as technology, craft, science or art, has deluded the paradox of the notion of architecture. He maintains that architecture should be viewed as a multi-disciplinary, multi-skilled, multi-dimensional and multi-media practice, within which a self-sufficient knowledge strives on the self-reliance and generation of knowledge. Teymur suggests four division domains of historical contexts, cultural contexts, physical contexts and social contexts. The appropriateness of forcing traditional teaching/learning paradigms into this new medium is yet another aspect to consider. In that regard, the Miller/Padgett model of efficient and effective distance education was used (Miller & Padgett, 1998). Miller & Padgett three-dimensional model addresses place, group size, and time formulate the various dimensions of the conditions both inherently found and needed in a successful distance learning environment. The distance education environment takes place in real time (synchronous) and part of it renders at students' discretion (asynchronous). With the help of this model, current topics in CAAD were embedded to meet the needs of the CAAD distance learner.

9. CAAD Systems Models

Bachelor of Science in Architecture Technology:
Computer Aided Architectural Design (CAAD)

A bachelor's degree in architecture technology with a concentration on computer aided architectural design (CAAD) provides students with hands-on application-oriented education pertaining to both architecture and information technology along with the real world buildability and CAD. This degree can be completed through distance education with various flexible options. The freshman and sophomore requirements can be fulfilled either at a pre-entry level on campus or through distance education at an equivalent community
college level. The junior and senior level courses can be obtained through Instructional Television (ITV) from the University (excluding lab courses unless a virtual lab is available.)

Information Technology (IT) using PCs as a Medium/Tool has reformed the design process thus affecting to great extent architectural tuition and, consequently, the built environment. Therefore, CAAD course through DE emphasises design using state-of-the-art equipment and practices. Graduates are employed by mechanical, industrial, and biomedical engineers, construction related industries, and graphics/advertising firms. Once initiated, the CAAD program should be accredited by the appropriate Accrediting Commission of the Accrediting Board at the designated country.

9.1. Suggested CAAD Degree Requirements:

*University Core Courses* (68-80 hours)

English: Vocabulary and Technical Writing (6 hours)
ENGL 1
ENGL 2
  Local Language (for non-English speaking Countries) (6 hours)
LANG 1
LANG 2
Mathematics (6 hours)
MATH 1
MATH 2
Natural Sciences (6 hours)
PHYS 1
PHYS 2
Social Sciences (6 hours)
Cultural Heritage (6 hours)
Military Practice (3 hours) (applicable to some countries)
Country History (6 hours)
HIST 1
HIST 2
Country Government (6 hours)
POLS 1
POLS 2
Physical Education (2 hours)
PHED

*General Technology* (9 hours)
CIVT
ITEC
TECH

*CAAD Core Requirements* (45 hours)

Introductory CAAD Stage:
*Intro to CAAD*
*CAAD Seminar 1*
CAAD Computer-aided architectural design 1
CAAD Programming 1
CAAD Virtual Studios: Designing with Computers 1

Intermediate CAAD stage:
CAAD Seminar 2
CAAD Computer-aided architectural design 2
CAAD Programming 2
CAAD Virtual Studios: Designing with Computers 2

Advanced CAAD Stage:
CAAD Seminar 3
CAAD Computer-aided architectural design 3
CAAD Programming 3
CAAD Virtual Studios: Designing with Computers 3

Graduation Project
CAAD Virtual Studios: Designing with Computers 4

*Computer Drafting Design (12 hours)
CADD 1
CADD 2
CADD 3

*CAD Electives (6 hours)
Elective
Technical Elective

*Free Electives (6 hours)

*CAAD External Course (6 hours)

*Supplementary Courses (12 hours)
• Structures
• HVAC
• Environmental Control Systems
• Scheduling/Project Management

In order to graduate, students must complete a minimum of 138 semester hours (36 hours must be advanced) with the last 30 hours in residence. However, Up to 66 hours may be transferred from a community college. In addition, students must also pass a Writing Proficiency Exam.

9.2. Description of Required Architecture Technology Courses

For CAAD model course, the students should register in the Bachelor of Science in Architecture Technology. Enrolment of students who must have access to a computer with Internet capabilities, is indeed not limited, but
depends on the facilities and staff provided by the institution. Students admitted to CAAD program self-described level of experience ranged from novice to knowledgeable. CAAD program, new students and new to the online environment are introduced to a number of courses to help them behave, and get clear guidelines about what is expected of them in online discussions.

Contemporary Issues in architectural design and CAAD, given to students through CAAD seminars, provide the student with the opportunity to explore professional issues and human values related to contemporary CAAD issues. Since learning to use the technology effectively is an important skill to be acquired early in the teaching process (Gunawardena, 1992), students were required to complete the university's online tutorial whenever applicable. CAAD teaching strategies included selected readings, online asynchronous and synchronous classroom discussion, research, guest and student presentations, and CAAD projects.

* Lab courses must be taken on campus, unless prior arrangements have been made with the instructor. Some laboratory work may be completed at home or work; other lab work must be done on the main campus, usually on weekends.

**General Technology (9 hours)**

CIVT : Graphics Cr. 3. Concepts and practices in lettering, geometric construction, multiview and auxiliary projections, sections, dimensioning, and isometric and oblique pictorials. Emphasis on freehand sketching.

ITEC : Technical Communications Cr. 3. Procedures and techniques of preparing technical memoranda, oral and written reports, manuals, and other source documents that fit the pattern of industrial and institutional communication.

TECH : Computers in Technology Cr. 3. Introduction to computers and their application to various disciplines. Concepts of hardware, software, number systems, basic computer organisation, and structured programming.

**CAAD Core Courses (45 hours)**

Introduction to CAAD Cr. 3.

Seminar Oriented (Video + TV channels)

STRUCTURES: This is an interdisciplinary seminar, whose goal is to reason on a series of fundamental questions that affect altogether such different fields as art and architecture, perception, architectural theory, computing, and philosophy. The seminar is divided into five distinct parts, each having the notion of STRUCTURE as a common denominator: TEXT, SHAPE, OBJECT, SPACE, and LIGHT. A weekly theoretical introduction on the subject is followed by an exercise. Starting with the first exercise, students present their work on the Internet.

The following computer tools / programs are introduced and used in the exercises: Unix operating system, HTML, XV, Adobe PhotoShop, AutoCAD, VRML, and Cosmoworlds.

CAAD Case Studies Cr. 3
This is an individual study dedicated to the modelling of an architectural object. The outcome of this individual study is a two-dimensional and three-dimensional representation of the studied object. In addition, a written report summarising the major features of the CAD program being used and comparing it with previously used programs or modelling techniques is required. The following programs are available for use: AutoCAD, Microstation, Archicad, Architrion, FormZ.

CAAD Virtual Studio:
CAAD Designing with Computers 1, 2, 3, 4, Cr. 4 (a total of 16 Cr. hours)
This is a core course of the CAAD degree. Students are obliged to attend the lectures and do the exercises.
In this course students have the opportunity to use the computer in the design studio.

CAAD Programming Cr. 3
The goal of this course is to teach students basic programming skills in AutoLISP, as well as an introduction to higher level languages, such as C, C++, and Java. The course consists of a series of lectures followed by exercises.

CAD External Courses Cr. 6
Upon approval by the program advisor, a student selects a course from a related discipline such as Computer Science, Robotics, Computer vision or Neurological Sciences.

CAAD Seminar:
Architectural Analysis and Representation: Cr. 3
The goal of this seminar is to make a comparative analysis of the different conceptions of architecture that are embedded in the projects of famous architects like Le Corbusier, Mies, Aalto, Terragni, Rietveld, and Loos. Internet is the medium in which this analytical work is carried out. Computer tools are to represent architectural works, to search for new relationships between concepts, and ultimately to convey a new conceptual framework derived from the intertwining of computing and architecture. In this seminar, students acquire the necessary knowledge in PERL and CGI scripting that enables them to create web sites displaying dynamic pages and handle Internet-based databases.

CAAD Computer-Aided Architectural Design 1 + 2 Cr. 4 (a total of 8 Cr. hours)
This is an elective course of the Architecture Department. Students are obliged to attend the lectures, but they do not have to do the exercises.

Computer Drafting Design (12 hours)

CADD 1: Computer-Aided Design Drafting I (Lab) Cr. 3
Introduction to commercial CADD systems, and computer graphics hardware and software programming in two and three dimensions.

CADD 3: Computer-Aided Design Applications (Lab) Cr. 3
Use of commercial CADD software for mechanical, civil, and architectural technology applications. Substantial design programming required.
10. References:
Aoki, Kumiko and Donna Pogroszewski. 1998. "Virtual University Reference Model: A Guide to Delivering Education and Support Services to the Distance Learner" Online Journal of Distance Learning Administration, Volume I, Number 3, Fall 1998 State University of West Georgia, Distance Education Center.
Moore, Michael G. 1996. "Tips for the Manager Setting Up a Distance Education Program." The American Journal of Distance Education, 10, no. 1:1-5.
## Appendix

A Comparative Analytical Review of the Distance Learning Programs at a Number of Universities World-Wide.

<table>
<thead>
<tr>
<th>OPEN UNIVERSITY/ INSTITUTION NAME</th>
<th>PROGRAM/S</th>
<th>GRADUATE/UNDEGRADUATE</th>
<th>DELIVERY MEDIA</th>
<th>(See #)</th>
<th>EVALUATION</th>
<th>RESIDENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Wealth Open University</td>
<td>BA &amp; BSc, MA, MSc &amp; MBA PhD</td>
<td>Grad &amp; Undergraduate</td>
<td>Internet</td>
<td>NA</td>
<td>Assignments &amp; A Final Project</td>
<td>None</td>
</tr>
<tr>
<td>The Open University</td>
<td>BA &amp; BSc, Diplomas &amp; Certificates, Postgraduate Certificate in Education MBA Taught Higher Degrees Research-Based higher degrees</td>
<td>Grad &amp; Undergraduate</td>
<td>Internet Online Conferencing, Printed texts, Computer Software, Videotapes, television broadcast</td>
<td>NA</td>
<td>Assignments &amp; Final Examination &amp; Project Work</td>
<td>For Some Courses</td>
</tr>
<tr>
<td>The Open University Israel</td>
<td>Life Sciences Natural Sciences Mathematics Computers Sciences Social Sciences Management Jewish Studies Education Humanities Psychology Communications Music &amp; Art</td>
<td>Bachelor</td>
<td>Textbooks, Satellite, Computer-mediated studies, Telecourse, multimedia &amp; internet.</td>
<td>NA</td>
<td>Assignments &amp; Exams</td>
<td>None</td>
</tr>
<tr>
<td>Massey University</td>
<td>Business Studies Social Sciences Humanities Education &amp; Information Mathematical Sciences Agriculture Horticulture Science &amp; Technology</td>
<td>Undergraduate Certificates &amp; Diplomas Bachelor Degrees</td>
<td>Printed study notes &amp; readings, e-mail &amp; Internet, audiocassettes, videotapes</td>
<td>NA</td>
<td>Assignments &amp; A Final Examination</td>
<td>Partial Attendance (Optional)</td>
</tr>
<tr>
<td>The Open University of Orlando/ Florida</td>
<td>Bachelor's &amp; master's Degrees in Enterpreneurship</td>
<td>Grad &amp; undergraduate</td>
<td>NA</td>
<td>Residence Program &amp; Non-Residency Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston University</td>
<td>Manufacturing Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACADIA University</td>
<td>Arts, Purge &amp; Applied Science Professional Studies Theology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUBRN University</td>
<td>MBA Engineering Acrospace Chemical Civil Coup.S. Industrial Materials Mech.</td>
<td>Videotapes, email, Internet</td>
<td></td>
<td>On Campus oral exam, and a written thesis</td>
<td>1 quarter of Full-time residency</td>
<td></td>
</tr>
<tr>
<td>Rochester Institute of</td>
<td>BS Applied Art</td>
<td>Intranet on-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

196
<table>
<thead>
<tr>
<th>Institution</th>
<th>Offered Degrees</th>
<th>Delivery Methods</th>
<th>Written</th>
<th>On-campus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Sciences, BS Engineering, Elect/Mech. or Manufacturing Technology, MS Environment management, MS Software Development, MS Information Technology, MS Health Systems</td>
<td>line course materials, on-line testing, On-line conferencing, Email, fax &amp; phones, Audiotapes, electronic blackboards, Videotapes</td>
<td></td>
<td>3 weeks on Camps</td>
</tr>
<tr>
<td>New Jersey Institute of Technology</td>
<td>B Arts in information Systems, B. Sciences, MS Information Systems, MS Engineering Management</td>
<td>Telelecture (Video), Electronic Discussion</td>
<td>Written</td>
<td>3 weeks on Camps</td>
</tr>
<tr>
<td>Goucher College</td>
<td>MA in Historic Preservation, MPA in Creative Non-fiction, MP in Administration</td>
<td>Electronically by Telecommunication and E-mail</td>
<td></td>
<td>2 weeks on Camps</td>
</tr>
<tr>
<td>Chattanooga State Technical Community College</td>
<td>CAD/CAM Technology, Among others</td>
<td>Videocassette mailout, cable broadcast, on-line computer service</td>
<td></td>
<td>Identical of 2nd year degrees of the college</td>
</tr>
<tr>
<td>MIT</td>
<td>SDM System Design &amp; Management, Industrial (Product Development)</td>
<td>Mixture of real-time MIT courses, via videoconferencing and videotapes</td>
<td>Same Curriculum</td>
<td>Fewer Visits to campus</td>
</tr>
<tr>
<td>Syracuse University</td>
<td>Under/ Graduate: MA in Advertising, M of library Science (MLS), MS Communication management, MS Telecommunications Management, MS Nursing, MS Social Science, MBA, Associate of Arts, Bachelor of Arts in liberal Studies</td>
<td>Mail, Telephone, fax, Computer</td>
<td>Identical</td>
<td>Limited</td>
</tr>
<tr>
<td>New York University (The Virtual College)</td>
<td>MS management Control Systems (4 Years), Certificate in information Technology, Advanced Prof. Certificate</td>
<td>Digital Network (Lectures, Seminars and Labs)</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>
Ra'Ed QaQish, Khaled Tarazi

<table>
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<tr>
<th>APC) 2 Years</th>
</tr>
</thead>
</table>

# Similarity to On Campus Courses
MODULAR ARCHITECTURAL GROUPINGS FROM ESCHER PERIODIC TESSELLATIONS

AUTHORS
Roberto Hugo Serrentino
Facultad de Arquitectura y Urbanismo
San Lorenzo No. 408
Tucuman (4000)
Argentina
rserrentino@arnet.com.ar
rserren@herrera.unt.edu.ar
Labsist@herrera.unt.edu.ar

ABSTRACT
One of the more interesting design techniques developed by Dutch graphic artist M.C. Escher consists in covering the plane with tiles containing patterns that repeats periodically. Modularity within shape grouping is extensively used, expressed by natural figures from the living world, and also from worlds of fantasy. This paper attempts to use Escher’s ideas as a source of inspiration to obtain modular shapes to conform groups with architectural issues.

The task is to satisfy design requirements and to get repeatable unitary shapes, whose geometric description is modularly manipulated within area as well as perimeter.

This should be done by two procedures:
1. from the components to the whole (from the tiles to the tiling): once the designer has defined a modular constructive unit (solving a particular situation), it is possible to repeat the unit to generate modular groups, knowing that they will fit perfectly among them, without gaps nor overlaps.
2. from the whole to the components (from the tiling to the tiles): defining a tessellation with the particular rules that drives close to the architectural solution, and getting the necessary units from the tiling.

There are multiple architectural themes on which this should be performed. School class-rooms, habitation buildings, shopping center sites, hotel rooms, are examples of this statement.
Analyzing procedures followed by the artist, particularly those using figures that tessellate the plane periodically, we’ll be able to generate tiles with architectural shape by the same way, applying different symmetry rules. Once the rules to generate shapes of tiles are known, we work within area and perimeter to satisfy modularity requirements and to convert the tiling as a geometric precise support for the insertion of architectural objects that follow predetermined dimensional patterns. In order to illustrate these ideas an example of grouping repeatable habitation units is presented.
MODULAR ARCHITECTURAL GROUPINGS FROM ESCHER PERIODIC TESSELLATIONS

Introduction
A tiling or plane tessellation is any arrangement of polygons fitting together covering the whole plane just once, without overlapping neither letting empty spaces (interstices). Every side of each polygon belongs also to one other neighboring polygon.
If we look for the meaning of the word tessellation in the specialized literature (1),(2), we shall find a few synonymous such as mosaics, tiling, grids, reticulations, lattices, even space-filling surface patterns. In the text of this work we will use the words tessellation and tiling indistinctly.

The art of tessellating must have originated very early in the history of civilization and, throughout different periods, its techniques always attracted artisans and all kind of people who wish to apply geometric ideas in their work. Architects, decorators, painters, quilters, between others, have made use of tiles either as some imaginary support of shapes, as well as constructive units to be located on flat surfaces and the like.

Every known society seem to have emphasized different aspects while using tiling:
• Mediterranean cultures such as the Romans were concerned with portraying human beings and natural scenes in intricate mosaics, usually made up by very little pieces.
• Many floors and walls of stately Greek and Roman villas were tiled with the same patterns we know today as our most traditional patchwork designs, including triangles, quadrilaterals and hexagons.
• The Moors and Arabs characterized themselves by the use of a very few shapes and colors to build up complex geometric designs. Famous examples are to be seen in The Alhambra at Granada in Spain.
• Nowadays, by contrast with another cultures, square and rectangular tiles seem to be almost universal, because of its practicality and constructive easiness.
• M.C. Escher, (1898-1972), was a truly pioneer in the use of tessellation with a great sense of generalization, and this is the fact we must rescue and emphasize. He was an unusual artist, driven by a desire to solve problems which may seem more relevant to the mathematician than the printmaker (3). Working with symmetry operations (translations, rotations, glide reflections and their combination), he invented a method to cover the plane with organic living shapes, sometimes from real world, others from fantasy worlds. Motifs which frequently appear include fishes, lizards, birds, sea and landscapes. And here is where we ask this question : Why not? Why these (in some way architecturally strange forms composed by bizarre shapes) could not be a geometric support for an architectural application? Why could not these shapes be modular ones?. We should explore this modular design strategy employing periodic tessellation inspired by Escher’s art.
Concepts and definitions

Actually, for our cultural background, we can say the word “tessellation” comes from the Latin “tessellae”, which was the name given by the Romans to the small tiles used for pavements and walls in ancient Rome. A tessellae is precisely a tile that follows the restriction to fit with others without overlapping neither letting empty patches. Geometrically, a tile is a plane region with laminar structure, whose boundary is limited by a closed curve made up by line segments.

A regular tessellation is composed repeating the same shape again and again covering theoretically the whole Euclidean plane. If this is possible by only one kind of tile, the tiling is called monohedral. The word monohedral means that every tile in the tiling is congruent with another of the same tiling by means of a translation, rotation or reflection. More simply said, all the tiles are the same size and shape. In this way, if the tiling is monohedral, a prototype tile is available. We should call it a prototile. Also in the case that a set of tiles is congruent to another set of tiles of the same tiling, preserving the property of being a new composed tile covering the plane without gaps nor overlaps, we say that this set is a composed prototile.

Figure 1: Simple prototiles.

Figure 2: Composed prototiles: tilings (b),(c) and (d) are made up combining simple tiles from (a).

It is also possible to tessellate the plane with more than one kind of tile, and depending on the number of them, it will be called dihedral, trihedral, 4-hedral..., k-hedral tilings in which there are two, three, four, ..., k distinct prototiles.
When a tiling admits any symmetry operation besides the identity symmetry, then it will be called **symmetric**. If its symmetry group contains at least two translations in non parallel directions the tiling will be called **periodic**. In other words, a periodic tiling is one that admits a periodic repetition of its shape along two non parallel translations represented by a pair of vectors \( \mathbf{a}, \mathbf{b} \). In fact, the symmetry group contains all the translations \( n\mathbf{a} + m\mathbf{b} \) where \( n \) and \( m \) are integers. The periodicity arises when shapes repeat themselves in regular distances and it is also called **cyclic distribution** of the plane surface. Its structure is denominated **lattice**. Starting from any fixed point \( O \), the set of images of \( O \) under the set of translations \( n\mathbf{a} + m\mathbf{b} \) forms a lattice.

One of the most well known examples of a lattice is the set of points with integer coordinates belonging to the Euclidean plane, configuring a regular tiling formed by squares called the **unit square lattice**. Generalizing even more, a lattice can be regarded as consisting of the vertices of a parallelogram tiling. Thus, with every periodic tiling is associated a lattice, and the points of the lattice can be regarded as the vertices of a parallelogram tiling. This should be presented in many various manners. If we know the interior configuration of one parallelogram, it is possible to build the rest of the tiling by repeating this configuration in the whole set of parallelograms.
A lattice of points in the plane and some parallelograms whose corners coincide with points from the lattice. Each of these parallelograms is a prototile of a parallelogram tiling whose vertices map the original lattice. All such parallelograms have equal area. Any of them could be chosen as a prototile regarding that no lattice point lies in the interior or on the boundary of any parallelogram.

A periodic monohedral tiling containing a design pattern (a motif) that repeats in every tile interior.

One possible periodic parallelogram from the tiling indicated in (b).

There are a few more considerations to do about classifying tilings and tiles, in relation with symmetry and congruence (4). This will help to recognize which kind of tessellation we are dealing with. Let’s consider two tiles $t_1$ and $t_2$ of a tiling $T$. They are said to be equivalent if the symmetry group $S(T)$ contains a transformation that maps $t_1$ onto $t_2$. The set of all tiles of $T$ that are equivalent to $t_1$ is called the transitivity class of $t_1$. If all tiles of $T$ form one transitivity class, we say that $T$ is isohedral or tile-transitive. Let’s see a few examples of isohedral tesselations.

Although the distinction between isohedral tilings and monohedral tilings may seem slight, it is not. Finding and classifying all monohedral tilings is an unsolved problem, (even in the case tiles are convex polygons). Nevertheless, it is possible to describe and classify all the isohedral tilings, fact that marks the difference. The name a tiling will receive depends on the amount of transitivity classes it has. If $T$ is a tiling with precisely $k$ transitivity classes then $T$ is called $k$-isohedral.
If the symmetry group $S(T)$ of the tiling $T$ contains operations that map every vertex of $T$ onto any other vertex, then we say that the vertices form one transitivity class, or that the tiling is \textit{isogonal}. Examples of this kind are the three regular tilings, those composed only by squares, only by equilateral triangles or only by hexagons. Also there are a lot of isogonal tilings that are not monohedral. See some examples in the following figure.

Figure 7: Examples of isogonal tilings.

A tiling is \textit{k-isogonal} if its vertices form $k$ transitivity classes, where $k \geq 1$ is any integer. A \textit{monogonal} tiling is one which every vertex, together with its incident edges, forms a figure congruent to that of any other vertex and its incident edges. The distinction between isogonal and monogonal tilings is analogous to that between isohedral and monohedral tilings. Figure 7(a) is a dihedric tiling that also is monogonal. It is important to mention a last concept about classifying tilings: those in which every edge can be mapped onto any other edge by a symmetry of the tiling, are called \textit{isotoxal}.

During his entire life Escher used this distribution system as the most important theme of his work, including in the geometrically pure tiles designs expressed by natural, organic shapes from the living world and also from worlds of fantasy and imagination. Such tiles can adopt any polygonal shape, segmented enough number of times to simulate a very smooth curve if necessary. This little trick allow us to obtain configurations that seem to be any kind of imaginable natural or artificial object, geometrically complex.
There are a lot of architectural themes in which once the designer has defined a building unit that solves a typical situation, it is possible to repeat the unit to conform groupings (this is an inductive-synthetic method of design process, which goes from the pieces to the whole).

In the same way, we can start from a group of shapes and recognize a single unit, or recognize a smaller group that solves a particular situation (this is a deductive-analytic method of design process, which goes from the whole to the components).

Classrooms in a school, dwelling in habitation sets, stores in a shopping center, hotel and motel rooms, are examples of this statement. If we can get a unitary repeatable shape, whose geometric description is modularly driven on its area and on its perimeter as well, satisfying design requirements, the digital work proposed in this article is effectively possible. The first step configuring architectural layouts is to determine a shape according to a mental prefiguration from who is conceiving it, exploding some main "force idea" or designing intention. On the other hand, almost every shape (two dimensional form) can be synthesized geometrically by means of some kind of polygon, generally non regular, particularly closed. This work proposes to obtain shapes of recognizable elements, natural or artificial, that preserving its geometrical structure (without altering its form), have a determined area and a modular perimeter. In other words, its perimeter has to be partitioned into modular line segments, without changing the original required area.

To obtain these shapes is necessary to work on the perimeter of basic polygons, the ones we are sure that tessellate the plane monohedrically. The polygons act like directress figures, and should be modified following very particular generating rules that let us get the tiles without gaps nor overlaps, once modified (5).

**Tiling with basic polygons**

Before we enumerate the generating rules to get tiles and tiling shapes Escher alike, it is convenient to analyze which kinds of basic polygons have the property to tessellate the plane monohedrically. Not only regular polygons tile
the plane, some non-regular ones can tessellate under a few restrictions. Besides, it is not strictly necessary that the directress figures were convex to tessellate the plane.

An obvious condition to tessellate with any figure is that arranging them around a vertex, the sum of the angles must fill 360 degrees. The following figures show two ways by which any triangle (even scalene) tessellate the plane.

Figure 9: Tiling generated by scalene triangles by the technique of rotations around midpoints.

Figure 10: Variation of the technique: rotating the triangle three times around the midpoints, then reflecting these triangles across the axis, creates a pattern that will tessellate.

The other cases by triangles are inside the general case. An isosceles with two equal sides and one not equal, also gives a parallelogram when we operate in the same manner. An equilateral triangle and therefore equiangular is a particular case of isosceles. A rectangular triangle working this way results in a tessellation of rectangular quadrilaterals.

Analyzing which quadrilaterals tessellate the plane, the conclusion is that every convex polygon with four sides do tessellate: squares, rhombs, rhomboids, parallelograms, rectangles, trapezes, trapezoids, scalene quadrilaterals. Some of them tile the plane by pure translation (square, rectangle, rhomb, parallelogram), the others require rotation or reflection besides translation. It is also possible to tile the plane with non-convex quadrilaterals, in the same manner triangles do.

Rotating a quadrilateral around the midpoints of its sides produces an arrangement that will tessellate. Once we have a pattern formed by four quadrilaterals, we can get the tiling by pure translation.

The sum of the interior angles of any pentagon is 540 degrees. Thus, it is not possible to fit all the angles of a pentagon into 360 degrees. Therefore, the technique of rotating about the midpoints of the sides will
not work with pentagons. Nevertheless, we can try to limit the technique with some geometric arguments that let pentagons tessellate the plane surface.

1. If two adjacent angles of a pentagon total 180 degrees, then the pentagon will tessellate in one of two ways: by translations or by reflections.
2. A special type of pentagon that has two non-adjacent right angles (congruent 90 degrees angles) and two pairs of sides of equal lengths (two pairs of congruent sides). Taking advantage of the equal side lengths and the convenient 90 degrees angles, it is possible to create a pattern where the right angles all meet at a single vertex.
3. If a side of a triangle is broken up in a way that the pentagon thus formed can join to itself, broken end to broken end, the pair of pentagons then acts like a parallelogram.

Figure 11: Examples of tilings with non-regular pentagons.

There are a lot of examples in nature that show tilings with regular hexagons (bees panel, trees cortex, chemical structures, etc). Also tessellate the plane those hexagons that have parallel sides two on two and, curiously, are the ones that dissecting them in two portions with a partition line crossing over the gravity center, let us get two quadrilaterals (we have already seen that they have the property to tile the plane). A pair of techniques can be applied to get non-regular hexagons that tile the plane surface. If we start with a parallelogram, and then create two sides from each of two opposite sides, we get some kind of non-regular hexagon. Making some specific movements it will tessellate by translations and by rotations.

Another way to make a tiling with hexagons consists in drawing first any quadrilateral, then divide one of the sides in halves and create new two sides from one of the halves. Rotating the new sides around the midpoint to replace the other half and removing the old half, we are done creating the hexagon. It is easy to see that this entire new shape can be rotated around the midpoint and we get two hexagons joined as a parallelogram, figure that can tessellate, using translation to repeat the pattern.

Some other regular polygons such as octagons and dodecagons have the property to tile the plane surface in combination with other regular polygons, but they cannot tile monohedrically. It is also possible to tile the plane with non regular polygons with more than six sides, and it is not difficult to obtain these shapes modifying basic figures.
Rules to generate “Escher tiles" from basic polygons.

As we have seen, choosing adequate directress basic polygons ensures the plane surface tiled periodically, by organic and other imaginary shapes. From this concept, we can announce the following generating rules which let us produce modifications on the basic polygons borders. The shapes obtained must admit design patterns in their interior, in the same way Dutch artist M.C. ESCHER used to.

1. **By translation.**

   Every portion cut on a side (concavity) is translated to the opposite parallel side (convexity). This rule can be applied to parallelograms and to hexagons with opposite parallel sides. The translation could be made only in the X direction, only in the Y direction, or both.

   ![Figure 12](image)

   **Figure 12.**

2. **By rotation with respect to the middle point of a side.**

   Every portion cut from the middle point of a side to one extreme (concavity) is added on the same side by a 180 degrees rotation, with center at the middle point of that side (convexity). This rule is applied to triangles and quadrilaterals.

   ![Figure 13](image)

   **Figure 13.**

3. **By rotation with respect to a vertex (hexagons and parallelograms)**

   Every portion cut on a side (concavity) of polygonal figures that have internal angles of 60 and 120 degrees, we turn it the mentioned angle and add this cut on the other side (convexity), with rotation center at this vertex. This rule is applied to hexagons and parallelograms. There is a restriction: in regular
figures such as a regular hexagon, the vertices center of rotation cannot be consecutive. It also should be applied to rhombs and rhomboids whose interior angles can have any value, with the same restriction: vertices center of rotation must be alternated.

4. **By rotation with respect to a vertex** (polygonal figures with one ore more 90 degrees interior angle)
Every portion cut on a side (concavity) of polygonal figures with an interior angle of 90 degrees, we turn it the mentioned angle and add this cut on the other side (convexity), with rotation center at this vertex. In case there is more than one 90 degrees angle the restriction is the same as before. This rule is applied to figures such as rectangular triangles, quadrilaterals and even pentagons with an angle of 90 degrees.

5. **By glide reflection with respect to a straight line.**
This means that once a design has been defined on the side of a basic figure, it is translated along a predetermined distance, an then it is reflected taking the mentioned straight line as the axe of reflection. This rule is applied to figures such as rectangles, squares, rhoms and isosceles triangles.

6. **By combination of translation plus rotation.**
This rule is applied to rectangles, modifying a side and translating the modification to the opposite side. Then, every portion cut from the middle point of the perpendicular side to one extreme (concavity) is added on the same side by a 180 degrees rotation, with center at the middle point of that side (convexity).
7. **By combination of translation plus glide reflection.**
This rule is applied to rectangles, modifying a side and translating the modification to the opposite side. Then, a glide reflection is applied to the other two sides: defined a design it is translated along a predetermined distance (the length of the rectangle), an then it is reflected taking a central straight line as the axe of reflection.

8. **By combination of rotation plus glide reflection**
Every portion cut from the middle point of a side to one extreme (concavity) is added on the same side by a 180 degrees rotation, with center at the middle point of that side (convexity). Afterwards a reflection axe is defined between two sides where the rotation wasn’t applied, and a glide reflection is executed. This rule is applied to isosceles triangles and quadrilaterals.

**Architectural Application**

From an architectural point of view, once the shape has been approximately preconceived, the procedure could be divided in two stages:
1.- the obtention of the functional required area
2.- the partition of the perimeter into modular line segments

The first stage is about locating the coordinates of the baricenter (gravity center of the figure), take them as the basis point to change shape dimensions, and by a proportionality relationship between original area and required area, we must find the coordinates of all the new points belonging to the perimeter, of the new scaled shape.

The second stage is about polygons resolution, working their perimeter in a modular fashion. Every polygon is defined by means of the coordinates of its vertices and the direction of the edges that join each pair of vertices. From each perimetral edge it is possible to obtain a partition with a great amount of new segments, each of them with a linear modularity assigned. Although a few vertices of theses new segments will modify their location once we made the modularity correction, the vertices from the original polygon must keep their coordinates.

The procedure starts assigning a linear value to the module. Then the distance between two vertices of the polygon is “forced” to take a multiple value of the assigned module, respecting the required shape. It could be a straight line segment or a circular curve arc, on each perimetral portion. The biggest difficulty shows up when we get to the last portion of each polygon or polygonal section, when it is required that even if we advance from left to right as well as from right to left, two points must coincide without altering the modularity.

This should be solved by the intersection of two circumferences which centers are the preceding point and the proceeding point to the one where it is required to obtain modular coincidence.

Figure 17: (a) Tiling Escher alike where the tiles simulate horses heads. Perimeter and area are modulated for the dwelling units. (b) A dwelling unit on the indicated configuration. The black dots are disposed at the same distance on the perimeter: equal modules letting insert modular architectural objects.

Working this way on every side of the basic polygon, with each segment of the modified polygonal, we obtain a 2D shape that encloses a predetermined area (required by the designing program) and also a linear modulation. Any
architectural element we want to insert to configure an electronic model, will have a linear modularity congruent with the generated tiles. To give an example, a grouping of little dwelling units is presented, satisfying a predetermined area and modularity.

Figure 18: A grouping of four dwelling units.

Being Design a subject that necessarily deals with shapes and forms, the use of geometry in a rational way, preserving economy, is worthwhile. An alternative consists in proposing procedures that help to obtain modularity within area and perimeter, letting the designer manipulate forms, without altering programmatic requirements. Operating with digital algorithms (6),(7) that take tessellations of the plane as a geometric basis, it is possible to redesign tiles and tilings Escher alike, to look for modularity and functional efficiency, with a great deal of design freedom.

Acknowledgments
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(1)  B. Grünbaum and G. Shephard  (1987) - “Tilings and patterns”.
(2)  Keith Critchlow (1982) – "Order in space".
(4)  Lionel March and Philip Steadman (1971) – “The geometry of environment”.
THE ARCHITECT, CAD AND TEACHING
THE PEDAGOGICAL POINT OF VIEW AT TOURNAI'S ISA SAINT-LUC

AUTHORS
Couwenbergh, J.-P.
Croegaert, A.
Gallez, B.
Petit, P.
Tilman, M.
Institut Supérieur d'Architecture Saint-Luc de Wallonie
Chaussée de Tournai 50
B-7520 Tournai
Belgium

ABSTRACT
Object-oriented approach to software development is discussed as a conceptual framework and working computational model for creative architectural design. Two modes of object orientation in design are elaborated. The more conservative mode is static, based on class-type/object-instance hierarchies. The other mode is dynamic, based on a modern view of computation as multi-threaded evolution of interacting objects.
1. INTRODUCTION
The IT revolution has definitively entered the domain of architecture. If computers and software programs are extremely effective tools, their applications and uses offer a variety of choices which belong to the architect. Thus, if most architects have in varying degrees integrated computer technology in their work tools, it is necessary to underline the existence of two very distinct tendencies as to the general philosophy of computerization in architecture.
On the one hand, a proportion of the profession categorically refuses to fit the whole architectural practice in a computer. They claim that the accuracy imposed by the machine and its peripherals transforms the artistic process into a cold, almost scientific methodology.
On the other hand, the second approach considers the computer no longer only as an improved drawing board, but as a partner that is capable of enhancing consistency of design in architecture. Used at the early stage of sketching, the modelling of the plan enables the designer to ensure its spatial consistency and to evaluate it from various points of view: integration into the site, exposure to sunlight, installation of the structure, calculation of surface areas, etc. This integration of all the elements of a plan, even if it is not yet fully achieved in practice, is, however, being set up.
Nevertheless, the true IT revolution in architecture will only be possible when future architects are better informed. Because they are too often viewed as separate disciplines, computer science and CAD in particular have too rarely been given access to the architect's workshop to be integrated naturally into project pedagogy. Learning any software program thus becomes an end in itself.
The purpose of the presentation will be to situate the pedagogical approach at ISA Saint-Luc Wallonie-Tournai, on the one hand, with regard to the learning of the architectural project, and on the other hand, as to the reality of the architectural profession.

2. PRESENTATION OF THE PEDAGOGICAL PROJECT
Is it necessary to teach future architects computer-aided drawing and design?
The notions of computer-aided drawing and design have been fully and better defined elsewhere. We shall not mention this aspect. However, using a computer for drawing is far from easy. Numerous experiments and assignments suppose the knowledge and common use of one or more design software programs. None of them gives explanations as to how to reach that goal. Leaving it to the students does not seem to be an adequate solution. Even if they can quickly understand the technical aspect of the software, they need guidance on how to acquire the learning and organisation method to be concretely applied to the architectural project, and used later in their profession. This is the objective at St-Luc Wallonie-Tournai School of Architecture.
Our intention is to present our initiative and the modest conclusions that 4 years of teaching have enabled us to draw. The intelligent use of a computer requires, on the one hand, necessarily structured qualities of a working and organisation method. On the other hand, it gives the student more autonomy in learning the various disciplines. We think these two characteristics are essential not only to the training of a future architect, but also to any training concerned with complex problems.

Our teaching method is based on the space of freedom afforded by the use of a computer and the opportunities of graphic expression it provides. We emphasize the learning of a working method rather than the learning and knowledge of a software program, even if the two aspects are interrelated.

3. TECHNICAL MEANS
The School has acquired 25 computers as well as a number of A1 and A0 plotting boards interconnected as a network and situated in a single classroom. The computer room also contains an A4-A2 printer. In the near future, the workshops for the last two years will also be equipped with computers.

Basic software: AUTOCAD.

These machines are available to students 24 hours a day all year long.

4. ORGANIZATION OF TEACHING
Here is a brief reminder of the use of computer technology in the 5 years of architectural studies:
- 1st year: introduction to word processing. Individual coaching facilities for courses of mechanics, stability and languages.
- 2nd year: introduction to "Windows", management of peripherals and handling of files.
- 3rd year: compulsory CAD course, including 4 hours (half a day) a week during the two semesters.
- 4th year: elective: 3D practice in connection with architectural projects.
- 5th year: elective: practice of computer generated images in connection with architectural projects. Introduction to office automation software.

In addition, the library catalogue can also be consulted on computer, which makes students' research easier.

4.1 1st and 2nd years
The programme for the first two years is organized in such a way as to enable students to acquire the appropriate training for the use of a word processor and a spreadsheet as early as the end of the first semester.

At the end of the second year, the students have received a good introduction to everything to do with the use of a computer and its peripherals.

Through these various approaches to the PC, the first two years enable the student to use the computer for various assignments, without having to practise drawing. We believe indeed that they should not learn CAD before they are sure to have acquired the elements of precision, decision and sensitivity by means of such traditional drawing tools as the drawing table, the T-square and the set square, etc.
In the same way, we believe that the introduction of information technology in the teaching of architecture made it absolutely necessary to keep and develop such more "traditional" courses as sketch drawing, for instance.

4.2 3rd year
The practice of computer-aided drawing being introduced in the third year, our main objective is to give each architectural student, whatever their means, the opportunity to master the computer which will become their "pencil" in their professional life.

The number of 3rd year students varies between 40 and 50. They are divided up into two groups.

During the 3rd year, we endeavour to familiarize students with what will inevitably become their pencil and his work tool. For this purpose we use AUTOCAD. No software has been designed to be taught. But does this type of software need to be taught? We will not give a detailed account of the reason why we chose this software, as this could be the object of another debate. Knowing AUTOCAD as such is not actually useful. But thanks to it we orientate our teaching through an intellectual approach which consists in abandoning the traditional drawing table. At the beginning the immaterial aspect seems puzzling: no 20 centimetre ruler, no pencil, no eraser. The screen is nothing but a window which moves around on the plan, whereas in the past the full image was visible on the drawing table. In other words, all this boils down to the disappearance of all traditional tools to which the student has become very much used and from which, as experience has shown, he/she cannot break away.

We thought it useful to begin with the teaching of two-D drawing, which provides a better link between the drawing table and the screen. After about 20 hours of teaching with AUTOCAD, we start the concrete application to a project in the planning stage in the architecture workshop.

- at Christmas, some students hand in the partial or full plan designed with the computer.
- the second term ends with the final plan. Students have to hand in at least one plate containing some element of the plan designed with the computer (plans, section or front).

4.3 4th and 5th years

Three-D and computer-generated images as design and communication tools
The new representation techniques, in the form of computer-generated images, provide drawing with a new dimension and a new reality, never achieved before. It is true that, even if in the architect's usual approach, drawing is both a design tool, which enables him to transpose his/her "IDEA" onto a concrete medium, i.e. the sheet of paper, and a communication tool, which enables him/her to transmit his/her plan to somebody else, traditional drawing cannot easily produce an overall perception of the plan situated in its context. Consequently, new representation tools are useful in that they provide an overall, virtual and three-dimensional vision of the project, compared with the classic two-dimensional approach split into plans. In addition, the visual exploration of the project, through successive sequences
of perspective views, seems to make it possible to reduce the distance between the project and its completion.

CAD tools combined with computer-generated images are thus above all, and beyond their visual attraction, on the one hand, design and study tools to visualize the plan, to check its overall consistency and detect possible flaws, and on the other hand, communication tools to present the project.

These two closely linked aspects are covered in the 4th year (Three-D design) and 5th year (computer-generated images).

**Three-D representation**

Until very recently the architect has always used the means of representation, such as perspective and the various plane projections, which date back to the Renaissance. Although this method has been used for a long time, one has to note its difficulty in representing architecture as a whole. As Bruno Zévi points out, it lacks the "fourth dimension". It is the latter which gives space its full reality.

Our spatial experience only depends on our progression in space. The various spaces visited can only be fully perceived in terms of duration. Thus, mobility of a person in space-time is a vital necessity for the apprehension of this space.

Equally, no spatial configuration is limited to a static and unique space, but to a succession of interrelated spaces. It generates a "spatial sequence".

"Mobility" and "spatial sequence" cannot easily be represented with traditional means which are essentially two-dimensional and static.

It is at this point that the computer with its developments in CAD and image generation makes a significant contribution. By generating multiple three-dimensional views and emulating the movements of a person in the space, through a "path", the architect is in an almost real situation, and his/her tool acquires a conceptual value thanks to its functions of control and assessment of a project in the planning stage.

The present objective of the 4th year course is two-fold:
- first, helping the student to perceive and understand the plan as a whole in 3-D space
- then, making him break it down into simple geometric figures from graphic primitives or surface-generating curves.

This process, which should at first sight seem easy for 4th year architectural students, does not appear to be simple for some of them. Producing plans on the drawing table has probably taught them to think in two-dimensional terms. With a three-dimensional designing tool such as the one used at our school, the student no longer draws a two-dimensional representation of his/her plan, but actually designs a three-dimensional full-scale model.

This approach to 3D takes place during the first semester (about 12 weeks) at the rate of 2 hours a week. It is progressive, beginning with the design of simple objects and proceeding to more complex assemblies.

During the second semester the more theoretical course of the first semester becomes a free workshop activity where the student can be helped by the teacher to integrate the data he/she has acquired into his/her project. The
final objective is indeed for him/her to achieve his/her end-of-year project with the help of the 3D CAD tools.

The software used is AUTOCAD 14 in its basic version. It enables the student to break down his/her project into basic elements rather than using pre-programmed objects. In future it will be possible to supplement this preliminary phase with a more specific application to architecture.

Design and communication in the 5th year
As a natural complement to CAD, image generation enhances the architect's conceptual approach. He/She can supplement the volumetric image of the project with other elements such as material, colour or impact of light. In addition, if the project has to be integrated into an existing site or structure, the architect will be able to study it as a fragment of the landscape.

The objective of the 5th year course is also two-fold:
- first, dealing with the aspects which have an impact on the student's conceptual approach: external appearance (material, texture, colour, ...), lighting (inside and outside), movements and perception.
- subsequently, tackling the communication aspects of the project with calculation of fixed and moving representations.

The course takes place during the first semester (about 12 weeks), at the rate of 2 hours a week. It covers the main elements of image generation: external aspect, lighting, visualisation, fixed images and animation.

During the second semester the more theoretical course of the first semester becomes a free workshop activity where the student can be helped by the teacher to integrate the data he/she has acquired into his/her own project. The final objective is indeed for him/her to achieve his/her end-of-year project with the help of the image generation tools.
The software used is 3D Studio Viz, the ideal tool to teach simulation. It makes it possible to establish a direct link with Autocad to appropriate 3D or to transform 2D elements into 3D. It is open, interactive, flexible, etc.

5. FUTURE PROSPECTS
The experience we have acquired over the last few years has enabled us to note that, generally speaking, students are increasingly open to using a computer because they have used one at home or at secondary school.

In addition, thinking of the very objectives of training for architects, we believe that the use of a computer cannot be restricted to the tasks which have until now been carried out with such traditional tools as the drawing table, for instance. In our view, the computer is too often used simply as a sophisticated transposition of the old drawing table, and its 3D potential is too often ignored. Whereas the ultimate aim of an architect's education is to teach him/her to see, think and work in space. The computer makes this possible, and this must be our objective.

Consequently, we are now considering restricting 3rd year student's training to the simple 2D operations with a view to dealing with 3D notions earlier, which corresponds to the architectural and town planning projects carried out in the
3rd year, i.e. the residential block integrated into its urban environment. Through manipulations of simple virtual volumes representing houses and blocks, students would be brought to directly handle positive as well as negative volumes. This stage is an adequate preparation for the scale model which, within the next few years, will be produced with the help of a computer.

In that event, 4th year students being used to the computer would more easily and rapidly go in depth into more complex 2D and 3D manipulations.
REMOTE COMPUTER GENERATED PHYSICAL PROTOTYPING BASED DESIGN

AUTHORS
Alvise Simondetti
School of Design
Hong Kong Polytechnic University

ABSTRACT
This research explores some of the opportunities offered by the field of computer aided design. It differs from much of the research in the field in the sense that it extends beyond the boundaries of the computer screen by building and testing a computational and communication design environment made of computers, computer peripherals and digital communication devices.

From our observation of the designer’s interaction with the computer generated physical prototyping systems we were able to confirm the unique haptic feedback and understanding of complex three-dimensional geometry. We also found limitations of the environment in relation to evolutionary design.

It was clear from those experiments with algorithmically generated design alternatives that potentially terrific opportunities lies in their combination with computer generated physical prototypes and manufacturing systems.
REMOTE COMPUTER GENERATED PHYSICAL PROTOTYPING BASED DESIGN

Introduction
This research explores some of the opportunities offered by the field of computer aided design. It differs from much of the research in this field (Mitchell, 1998) in the sense that it extends beyond the boundaries of the computer – what is commonly referred as “getting out of the box” – by building and testing a computation and communication design environment made of computers, computer peripherals and digital communication devices.¹

In this research we created a computer-based environment and observed a range of volunteer designers, in the early stages of their design process. The focus of our observation was how these designers interacted with the environment with the aim of exploring the environment’s advantages and limitations and found that it raised novel questions about research in Computer Based Environments. This ongoing research focuses on the exploration of the field of design for manufacturing using mass-customisation systems.

This paper describes (1) the computation and communication based environments, (2) the methodology used to conduct the experiments, (3) its advantages and limitations and (4) further possible research questions. The paper focuses especially on unexpected outcomes.

Two computation and communication based environment
The designers produced a three-dimensional computer model and then used Rapid Prototyping² systems to produce three-dimensional physical objects. The three-dimensional computer models where produced using both traditional software, including AutoCAD, Rhino3D, Alias, as well as algorithmically-generated design alternatives (Duarte and Simondetti, 1997), including rule based parametric methods and genetic algorithms. The Rapid Prototyping systems used were Fused Deposition Manufacturing (FDM) and Stereo-lithography (SLA), both available at the Industrial Centre in the Hong Kong Polytechnic University.

To enhance communication, the research team installed a series of video conferencing systems over the Local Area Network (LAN) using Classpoint Software for multi-point continuous (24 hours a day) connections between the designer’s workstation, the RP workshop and the observer’s workstation. We

¹ The computers used were: PC Pentium II, 300Mhz, SGI Indy, PC Pentium 166 Mhz. The computer peripherals were: FDM2000 by StrataSys, SLA 3500 by 3D Systems. The digital communication devices used were: PC Pentium II, 300Mhz NT Server for Class Point multi-point videoconference, PictureTel LIVE 200, Intel Proshare. LAN used was 100 baseT Networking system (UTP 100Mb/s).
² Rapid prototyping systems build three-dimensional objects according to the data provided by a three-dimensional computer model by depositing or solidifying various materials layer by layer.
wanted to simulate the studio environment in which the designer concurrently sketches and produces physical models, while being observed by the principal investigator. The designer made use of this set up for experiments that where conducted in the School of Design.

For experiments conducted outside School of Design, we used email. The designer would send three-dimensional computer files as email attachments, and then three-dimensional physical models were produced in University's Industrial Centre. Photographic images of the models were then sent back to the designer also as email attachments. The observation was limited to personal comments sent back and forth over email; only in one case was the physical model sent back to the designer in Australia.

It is worth mentioning that we always respected each designer’s inclination to use one traditional software or algorithm rather than forcing the designer to use those specific systems that better interfaces\(^3\) with current Rapid Prototyping (RP) systems. Our choice resulted in all designers producing surface models as oppose to solid models generally considered more appropriate for RP technologies. The same attitude made some of the experiments unique from a strictly technical point of view. The resulting experimental data about open and closed surface modelling and its implication in rapid prototyping systems will be the subject of another paper, by the project research assistant, Mr. Chak Chan Lewis.

**The methodology used to conduct the experiments**

To explore the limits of this fast evolving field of research and to secure immediate result we conducted a series of case studies that seen together give a sense of the range of possible interaction with this technology and opens questions for further discussion.

For example, to optimise the range of the experiments, the test group included designers geographically distributed in Hong Kong, India and Australia. Designers ranged from highly educated practitioners to first year degree students and even included a computer graphics programmer.

The aim of this broad methodology is to compare what designers do during the early stages of their design process, before and after the introduction of new technology. We then attempted to evaluate if and how their design process had improved by presenting the results to a panel of experts.

**Description of case studies**

The following case studies are listed according to: the designer’s level of experience and education, the stage of design development and the level of access to the in-house environment.

Micheal Cheng is a second year student in the BA(Hons) course in the School of Design. His knowledge of CAD software is above average within his class, although limited to the use of software for 3D visualizations. Michael interacted

\(^3\) For Example ProEngineer by Parametric Technologies, Unigraphics etc… In some cases designers used AutoCAD surface modeling and 3D Studio, in other cases the designers used Rhino3D instead of using solid modeling module or software.
with the in-house environment at a later stage in his conceptual design, when most of his decisions had already been made. Michael was able to fully and repetitively experiment with the in-house environment.

Manit Rastogi practices and teaches Architecture in New Delhi, and has previously carried out research in design and computation (Frazer, Rastogi, Graham, 1995). Manit has an expert understanding of CAD, CAD programming and architecture. He did not interact with the in-house environment. He emailed the design to the principal investigator who generated a physical model and emailed an image of it back to him. Manit produced a Genetic Algorithm code in AutoLISP for AutoCAD to generate the design. He generated a three-dimensional cellular automata (CA) using closely packed spheres (Frazer, 1995). The designer used a mapping algorithm that generates surfaces through the points of the CA. The complexity of the surface is controlled by the complexity of the rules of the CA generated using genetic algorithms that in this case evolves for increasing complexity. The designer has frozen one instance of the evolutionary data space and produced a physical prototype.

The code generated a surface model of the design with intersecting surfaces. The AutoCAD software couldn’t export the .stl file necessary to prototype the design. A utility software, downloaded from the WEB, was used to generate the .stl file.

Michelle Flowry, Grant Dunlop and Gregory Duncan are first year students in the Master of Architecture course in Deakin University, Australia. Their designs were produced for a course offered by Prof. Mark Burry, which is aimed at teaching “programming for enhanced CAAD productivity and design capability.” The students sent their files by e-mail and received images of their physical prototypes.

Benny Leung is a senior industrial currently teaching at School of Design. His three-dimensional computer model was created by his assistant, Benny did not interact with the in-house environment because he did not personally use the computer. His design was already partially developed. When Benny received the physical prototype this was his first reaction: “If we look at the drawing is not that thin, when you made the prototype something must have happened...”. He added: "I do appreciate the slightly translucent white colour." The designer’s reaction suggests that he is getting new types of feedback from the 3D prototype.

Chan Kwai Hung received graduate education in Computer Science. He is currently conducting research in the field tools for algorithmically-generated

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4 Most common 3D software, including AutoCAD, allow the user to export 3D solid geometry in STL format used by Rapid Prototyping systems. We used a freeware found on the Internet called STL_Util to export closed surfaces in STL format. As for open surfaces we manually applied a minimum thickness to be able to export in STL format. STL_Util 2.1, written by Benoit Michel, Rue de Sendrogne 100, 4141 Sprimont, BELGIUM, 1994, e-mail: 2:293/2202.12@FIDONET.ORG

Remote Computer Generated Physical Prototyping Based Design

designs in School of Design. Hung was mostly concerned about his process of developing a generative design tool. Therefore the design instance that was prototyped did not represent a memorable step in his process and did not produce the kind of feedback that is necessary for his work. Prof. Frazer, the leader in Hung’s research, commented that the physical static prototype represented a trivialisation of his evolutionary design, intended to be experienced over time, or in the fourth dimension.

**Advantages and Limitations of the environment**
The following comments are in addition to the results of previous research conducted in a similar environment by the author (Simondetti, 1998). In that earlier study major advantages to the designer offered by Rapid Prototyping Systems were identified in: haptic feedback, feedback on designs in motion and feedback on complex free-form designs.

Computer Generated Physical Prototyping Based Design environments evidently appear limited in providing the feedback necessary to help the designer proceed when confronted with a design, as in Manit’s and Hung’s case, that is an instance of an evolving data space. In a limited number of generations, these designs begin to show complex interpenetrated surfaces. From a technical point of view, interpenetrated surfaces proved challenging for the slicing software that prepares the files for rapid prototyping. The computer generated physical model made using FDM (fused deposition manufacturing) processes, proved to be hard to read because of their opaque and static qualities as opposed to the dynamic translucent visualisation offered by a rendering software. The SLA (solidified resin) prototype, with its translucent material, proved to be more readable than the opaque FDM one.

An interesting discussion also occurred around the issue of scale. In the virtual world designs evolving on the screen are scale-less. In the transition process from bits to atoms, the designer must specify a scale at which the design will be produced. By doing so, the visualisation offered by the computer generated physical models drastically limits its effectiveness to the designer. It was discovered that it is easy to imagine one self walking inside the data space when is dynamically evolving on the screen, but once it was prototyped with an overall size of 20x20x20 centimetres, that design did not appear to offer the same inspiration to the designer. The haptic feedback offered by the ability to hold the design, in these particular examples, appeared to be information of no use.

Global Virtual Design Environments, similar to the one recently set-up at School of Design, was suggested as a possible solution to the problem raised above. With its supercomputer for real-time multi-piping rendering and real-time design generation and its semicircular walk-in screen and 3D glasses, this environment promises to offer the designer the necessary four-dimensional interaction and feedback.

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6 This notation of what may be commonly referred to as Rapid Prototyping was found by the author, for the first time in William J. Mitchell, “Change, Time and Speed”, Thresholds no. 16, Dept. of Architecture, MIT, 1998.
However, when the designer is developing the design of an object that is meant to be touched, as in Michael’s design for a hand held pin collector, it was noted by professor Frazer, that “[...] none will dispute that having something in your hands and being able to turn it around, it makes it somehow very much easier to appreciate even than very dynamic images. There is something about its three-dimensionality and its tactile qualities that is more communicative to the brain.”

The success of Michael experiment is also related to the fact that the prototype of Michael’s design, was produced at full scale as opposed to a scaled representation, generally used for interior and architectural designs that tends to turn a building into an object, sometimes a toy.

**Further research**

It is clear from these experiments with algorithmically generated design alternatives that potentially terrific opportunities lies in their combination with computer generated physical models systems. My current research project in Design for Mass Customisation Manufacturing Processes is exploring these opportunities offered when a designer develops a series of parametric algorithms to generates families of designs that share selected parameters and differ one another according to some others.

From some of the comments by the panel of experts on the result of the experiments, it appears clear that designs algorithmically generated, as in the case of Mani’s and Hung’s, were perceived as much more appealing when represented as dynamic images on the screen if compared with their physical prototype. It was noted that screen representation offers a distorted view of the real design, and that may have made some designs look more interesting than what they actually would be, when prototyped. However this only an hypothetical observation, and a systematic testing that compares all sorts of representations, including dynamic rendering is necessary.

Computer generated physical models, as this research reinforces, are imposing themselves as an alternative representation for designers. Together with the development of Walk-In Three-Dimensional Virtual Design Environments, or CAVE, it seems that there is an opportunity to extend the research towards building a matrix of comparison with an historical perspective. The matrix may list design representations, including for example: pre-perspective, projected geometry, early computer aided design systems, early solid modelling, generative systems, Virtual Design Environments, Computer generated physical models and compares them according to criteria of appreciation including: tactile qualities, intelligibility, robustness and cost.

This possible development of the research will have a practical use, because it will offer guidelines to the inexperienced designer on which representation may be most appropriate to his/her necessity. It may also cast light on the too

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7 Notes from the panel of experts discussion conducted at School of Design, HKPU, January 1999.
often hidden relation between the representation used during the design process and final result of the design.

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http://www.ellipsis.com/evolutionary/evolutionary.html
SOME EXPERIENCES ABOUT CAAD ON DESIGN AND DOCUMENTATION PROCESSES

AUTHORS
Ricardo Cuberos Mejia
Research Institute
Faculty of Architecture and Design
University of Zulia
Maracaibo
Venezuela
rcuberos@luz.ve

ABSTRACT
The manuscript proposes a qualification of the added value of CAAD according to the scope of application of such platforms, their implications in the own design process and the character of its end items. Each scope as well is defined in different dimensions, which explain and exemplify from a series of experiences developed by the author in the last 10 years, applying CAAD platforms in activities of architectural design, university teaching, investigation and consulting, or urban planning.
SOME EXPERIENCES ABOUT CAAD ON DESIGN AND DOCUMENTATION PROCESSES

Introduction
In the last ten years, the application of computers on the resolution of design problems has gone evolving from the simple use of database systems, developments on two and three-dimensional modeling, until the generation of photorealistic views and path simulation through telematic networks. On this same way, CAAD systems have come incorporating new capacities that allow not only to obtain better and faster design and planning products, but that has even affected the own nature of the design activity. These factors constitute an important value added to the use of computers, which in opinion of this author affects two scopes of the architecture:

a scope referred to the design process, by which CAAD takes part in determining way in the methods and activities used for projects development;
and

a scope referred to the design products, in which the designer activities generate end items of a new nature, as much of the printed as of the magnetic thing.

Next, the way as these scopes are considered in the professional labor is explained and exemplified through projects developed by the author like part of their academic and professional activity: as Projects Manager of RVM Consultores consulting company, as Head of Information Systems in the Faculty of Architecture and Design of the University of Zulia, and as Architect in independent professional labor.

1. Scope of the design process
Considering the factors that affect the definition and accomplishment of a project, the added value of CAAD can be understood in a series of dimensions, which usually affect all design process. According the nature of the project, these dimensions are pronounced with greater or smaller emphasis, of the way that is explained in next the five subtitles.

1.1. Geometric - volumetric dimension.
The vectorial fundamentals of all CAAD systems implies that it does not matter frees it that tries to be an architectonic form, his generation and representation within the system will be always a precise, limitable and, even, three-dimensionable geometric function. It facilitates the best handling of the composition, since it allows establishing axes and vertices for structure the figures that define the components of a project.

The first example of this can be appreciated it in a house building with apparently "free" forms (figure 1). Its general base plant is composed by curve elements, whose attributes of centers and joints can be seen clearly indicated. Its different levels display a game of curved and straight traces that pretend to give an only dominant direction to all the lines of vision from its interior spaces. Figure 2 presents the geometric composition of a de-constructive office building, whose general plant shows a composition of curved elements similar to the previous example; in this case, such freedom has been applied to its
volumetric form, generating plans and vertices clearly quantifiables thanks to the three-dimensional geometric modeling.

The third example (figure 3) shows the volumetric rendered study of two alternatives on the design of a commercial building. The differences in the handling of the planes and covers in facades towards the public route allowed the selection of that project with the accent landmark instead on which it used vaults, since the client considered that this one represents better the institutional image of its car sale company.

1.2. Functional - spatial dimension.
For the harmonic perform of the activities within a building, it is necessary a correspondence between the sequence and interrelation of his spaces, and the uses that their inhabitants give the same ones. In those projects in where the functional complexity is considerable, CAAD offers diverse modalities of support to the programmed design of each area.

The characterization of each one of the jobs in an office, according to its organizacional hierarchy, its relation with the clients and to their own nature of activities, allows establishing a catalogue that facilitate the study of combinations of units. In figure 4, two alternatives of design generated from a same set of functional specifications are appraised with the help of LISP routines, in the search of a minimum area and an operationally "optimal" building.

The following case (figure 5) displays the application of the functional units in low-cost apartment blocks. Each one of them is conformed by space units with a "minimum" size according to governmental regulations and the local market, arranged under typical scheme social-service-private areas. In figure 6, another case of application of such specifications is exhibited, only that in this case and due to economic status profile of the apartments purchasers, the functional scheme is adopted in a less rigid and more expensive formal proposal.

1.3. Typological - stylistic dimension
Typology concept arises from the definition of a set of characteristics that allow identifying different objects under a same general qualification. In architecture, typology encloses formal, space and constructive values, understood under certain concept of "style" often extracted from historical architecture studies to be used with allegorical intentions. In this sense, CAAD has the capacity of the handling of predefined modules that can be used time and time again with some automatizables variants, according to a use of patterns decided by the designer.

In the first example (figure 7), we see the definition and application of stylistic patterns of facades and spatial units, for bank office buildings with high analogical value of Spanish colonial architecture. Each module has a set of formal, functional and volumetric particular characteristics within a CAD template, which allow the application of a certain architectonic language according to the corporate image of the company owner of the building.
This analogical character is also applied to a case of a cultural center showed in figure 8. The building, located in an urban sector characterized by the predominance of indigenous population, has been designed on the basis of determined structural-space modularity from the wood elements that constitute their columns, beams and covers. Such modularity induced to the handling of grids and meshes within CAAD for the distribution of walls and finishes.

The geometric managing of facades and volumes also can be used in allegorical way. In figure 9, the conformation of the facades planes and the space organization of its floors some way reflect allusive intentions to the appearance of an indigenous woman, it as generator principle of the design of an apartment block.

1.4. Normative - urban dimension
Like part of the normative body that regulates the construction of buildings, are the zoning ordinances. They establish the conditions of lot development, and contemplate design parameters in order to generate certain formal homogeneity towards the public routes within each urban sector. They are expressed, on the one hand, in maximum densities and construction areas, those which determine the size of the building, and on the other hand, in maximum occupation areas, number of floors, retreat of the building from the boundaries, minimum areas of arborization and numbers of parking places.

These parametric regulations affect the own form to work under CAAD. After to have calculated the qualitative and quantitative characteristics of the land use allowed in a parcel, the designer decides with the client the amount of space to being built, in meters, in independent units and in number of floors.

By virtue of it, CAAD activities begin with the tracing of the lot measurement according to its astronomical coordinates; after that, designer demarcates the limits of minimum retreat from the boundaries, within is formed the maximum occupation area legally allowed for the building. He studies the location of the number of required parking places, using different kind of parking blocks, as well as of the referential layout of the minimum green area; in function of all this, designer can define the structural modulation and the direction of the facades of the building. Figure 10 shows the base plant of a house building whose design seeks for the greater number of parking places and constructed service area without infringing the norm. The number of floors and the occupation area decided for each one of them on the project, correspond almost exactly to the permissible maximum. The reason of it responds to the interest of the promoter to obtain the greater amount of inhabitable and saleable built area over his lot.

In single houses, is appreciated the same interest by the maximum possible development, confined to the retreat from the boundaries and maximum height of the building (figure 11). The same thing happens with commercial buildings, in which the number of parking places generates the main restriction for the development, due to it is proportional to the commercial premise area to develop. Figure 12 presents a simple commercial building that responds the requirement of maximum built area without great pretensions of design, as well as two preliminary proposals of high-rise buildings generated on the basis of numerical exercises of the urban norms.
1.5. **Constructive - decorative dimension**
The activity of the decorative design of outer and inner finishes and forms, resides one way or another, in the geometric exercise with axes of formal organization, in the use of repetitibles patterns, and in the process of trial and error to evaluate the results. These activities are easily conducibles through CAAD, with the insertion of upgradeable decorative modules in plants and facades projections, and with the three-dimensional visualization of the modeled proposal on hidden lines or rendering views.

Figure 13 shows the final option of facades renewal of an apartment block. Three alternatives were created with a CAAD system, and they were appreciated and evaluated by the proprietors of the building. In base to the selected proposal were elaborated the final construction plans of the new finishes. The next example presents the intervention project of an old house building, to convert it into a bank office (figure 14). The existing outer decorations have been re-interpreted and repeated in new annexed parts of the building, generating a expressive language also used in the inner design as much in columns and walls as ceilings and furniture.

The use of directive lines, that define the patterns of showcases, ceilings and floors, is appreciable in the interior design projects of a shoe shops chain (figure 15). The contrasts between forms and planes are handled under a three-dimensional conception of the space, determining in sections and construction details the accents in height and shapes that characterize the decoration of these commercial premises.

2. **Scope of the design product**
Like fruit of any investigation or consulting activity, the items elaborated with a CAAD platform can have an implicit value in itself, as input for the accomplishment of another design or analysis activity, or as final presentation product of the professional service. Next, such implications are explained.

2.1. **As input for the analysis, the design and the planning.**
All application of CAAD tools generates drawings in magnetic format that can as well be used later for other analysis or planning activities. On urban scale, one of the most important uses of CAAD is to generate vectored urban planimetry for GIS (geographic information systems). Figure 16 presents a continuous set of urban centers, whose road structure has been traced from the manual vectorisation of raster planes using a CAD tool. Later, these base plans were integrated to a GIS to evaluate the location of hospitals and ambulatory centers that constitute the regional health service.

The following example displays the urban structure, the service equipment and the potential attractions for a tourist geographic information system of one regional capital city (figure 17). There, SIG layers with their corresponding attributive data are combined with referential CAD plans and with simple raster plans of the urban center.
From other points of view, the exhaustive graphical documentation of buildings can generate planimetric bases for the architectonic analysis. The first example shows the planes of facade of an historical hotel building on which a morphologic analysis is applied (figure 18). The use of golden rules and harmonic rectangles in facades is revealed when superposing them on the South view of the building. This kind of analysis also can be made three-dimensionally: the house showed in figure 19 was modeled in detail through a CAAD system to evaluate a series of parametric principles of the neopalladian architecture, like proportions of its vestibule and radial symmetry.

2.2. As generator of final products.
One of the elementary uses of all CAAD systems has been the one to facilitate the elaboration of the definitive construction planes of an architecture project. Almost all the examples described in this work concluded in printed plans with measures and details, of a nature similar to the one showed on figure 20. Due to facility in their heliographic reproduction, such plans usually are monochrome, with variants in the line thicknesses to add expression to their contents.

However, it exists other types of final plans that also can be generated by a CAAD, those that allow to the documentation of urban plans and projects. The example of figure 21 presents the detail of a zoning plane of urban intervention actions in a populated center, which by its complexity requires of the color for its better understanding. It is the same case of figure 22, in where a new road proposal on a regional metropolis and their toponymy are established in a illustration ad-hoc included in the urban plan

It is possible to include another type of final item that is not related to the printed documents: the vectored planimetry developed for the digital spreading of the values of buildings and places with historical or social importance. Figure 23 shows the interface of a telematic information service about buildings, which among its consultation modules, it includes the possibility of access and manipulation of the vectored planes of several buildings through a web browser. The last example (figure 24), expresses a sequence of virtual routes in an important urban place in the regional metropolis, which can be acceded under digital animation (with predetermined routes), or VRML through web browser (with interactive routes) through intranets or Internet.

Conclusions
The different modalities from the added value of CAAD that has been reviewed in this work are supported in a combination of automated and manual processes under a complementary way. It is because the added value is not only inherent to the computation tools used in each case, also to own factors that merge from the nature of the project, such as its theme, their scale, its purposes, their designers and their final users. For that reason, and in spite of the important increase in the capacities of the CAAD systems (such as the development of parametric design tools and "smart" CAAD), the computer aided architectural design will stay like "an eclectic set of applications, independent and unevenly applied in different aspects of the design and the documentation process" (Cuberos, 1998). Such discretionary application of CAAD clings to the inventive capacity of the designer and
planner, only methodologically regulated but inescapably freed under the humanist approach of an architecture as science and art of social service.

References
Figure 1: Lago Cristal Residences (R. Vargas, R. Cuberos, 1995, Maracaibo, 7325 m$^2$).
From left to right: base plan, 3D model, current photo.

Figure 2: Punto Fijo Maracaibo Bank office (R. Vargas, R. Cuberos, 1993, Punto Fijo, 980 m$^2$).
From up to down: 3D view, base plan and facade photo.

Figure 3: Autojapon car sale (R. Vargas, R. Cuberos, 1992, Maracaibo, 830 m$^2$).

Figure 4: Ciudad Ojeda Principal Bank office (R. Vargas, R. Cuberos, 1992, Ciudad Ojeda, 320 m$^2$).
From up to down: small and large office alternatives, 3D view, photo on 1995.

Figure 5: Las Palmas Residential Park (R. Vargas, R. Cuberos, 1994, Maracaibo, 4176 m$^2$).
Up: general base plan (detail). Down: artistic sketch based on 3D model.
Some Experiences about CAAD on Design and Documentation Processes

Figure 6: Residence Tower (R. Vargas, R. Cuberos, 1993, Maracaibo, 3000 m²). From left to right: apartments floor, artistic sketch, and current photo.

Figure 7: Latino Bank office design catalog (R. Cuberos, R. Vargas, Punto Fijo, 1993, alternative with 315 m²). Up: facades template. Down: final drawing of a proposal.

Figure 8: Indio Miguel Cultural Center (R. Cuberos, G. Bravo, 1995, Santa Rosa de Agua, 690 m²). Up: general base plan of the little island. Down: artistic sketch based on 3D model.

Figure 9: Miguel Angel Residences (R. Vargas, R. Cuberos, 1994, Maracaibo, 3350 m²). From left to right: apartment floor, current photo, Wayuu native woman dancing "yonna" with folklore dress on Paraguaipoa, near Maracaibo.
Figure 10: Da Vinci Residences (R. Vargas, R. Cuberos, 1994, Maracaibo, 3010 m²). From left to right: General base plan with normative limit shape, apartments floor, and current photo.

Figure 11: Milva House (R. Vargas, R. Cuberos, 1993, Maracaibo, 540 m²). Up: photo on construction work. Down: second floor, with main rooms.

Figure 12: Commercial and residential buildings (R. Vargas, R. Cuberos, 1993, Maracaibo). Upper left: Ciclobarca commercial center, 110 m². Right and down: preliminary studies for new housing projects in base to urban normative.


Figure 14: Indio Mara Maracaibo Bank office (R. Vargas, R. Cuberos, 1994, Maracaibo, 760 m²). Up: artistic sketch based on 3D model. Down: facade detail.
Some Experiences about CAAD on Design and Documentation Processes

Figure 15: Deportivos 2000 shoe shops (R. Cuberos & associates, 1994-98, Maracaibo) Up: ceiling plan of a 180 m² shop. Down: photo without furniture of a 512 m² shop.

Figure 16: Cities urban structure on the eastern coast of Maracaibo Lake, for the Regional Health Geo-referenced Information System (FAD-LUZ - Zulia State Government, 1998, Regional population: 2500000 inhabit.)

Figure 17: Maracaibo urban structure for a Tourism Geographic Information System SIGTUR (FAD-LUZ, 1998, Maracaibo urban area: 22000 has.)

Figure 18: Morphologic studies from an historic hotel building (FAD-LUZ, 1990, Maracaibo). Up to down: main facade, geometric study, current photo.


Figure 20: El Vigia Occidental Bank office (R. Vargas, R. Cuberos, 1992, El Vigia, 1213 m²). 3D model. Down: construction details.
Figure 21: Altagracia Urban Plan (FAD-LUZ, 1997, Altagracia, population: 32000 inhabit.). Land uses zoning plan.

Figure 22: Maracaibo Urban Plan (FAD-LUZ, 1998, Maracaibo). Road structure plan on AutoCAD interface.


Figure 24: Virtual paths on a Baralt Square 3D model (FAD-LUZ, 1998, Maracaibo). From upper left to right down: Lia Bermudez Art Center, Beco-Blohm Building, Tito Abbo Building, Saint Francis Church with Rafael Baralt statue.
THE DIGITAL SKETCH WORKSHOP:
A CORE COURSE IN DESIGN WITH COMPUTATION

AUTHORS
Reed Kram
Chalmers Medialab
Chalmers Tekniska Högskola
Vasa Hus 4
41296 Göteborg
Sweden
kram@medialab.chalmers.se

ABSTRACT
This paper summarizes DIGITAL SKETCH, a workshop that took place over the course of two weeks in September 1998 at Designskolen Kolding, Denmark. DIGITAL SKETCH was an attempt to create a foundation course in design for the digital medium for students with strong visual design skills, but little to no computer experience. Teaching design on computers is commonly thought of as detailing the current version of the latest commercial software. As long as this is the case, design on computers will (quite rightfully) continue to get little respect from those designers using more traditional design methods. How can we find the "core" of this medium when faced with the constant onslaught of operating system upgrades and version 11.2 of software Y83? For DIGITAL SKETCH, we tried to demystify the process of controlling the computer. In this workshop we examined the meanings of the term "sketch" as it applies to the design process on the computer. Our hope was that by revealing some of the unique characteristics of the digital medium, we might develop new design processes in tune with this medium.
INTRODUCTION: TOOL OR MEDIUM
Is the computer a tool for making design or a medium for design? Recently a number of researchers have proposed that the computer may be considered a medium for design [Bermudez 1998: 11]. If this is the case, what are the defining characteristics of this medium?

It is interesting that despite the ever-prevalent monitor display, the computer medium is not limited to the cathode ray tube. Computation is a separate realm that may or may not be connected to a monitor. Its aesthetic may or may not be visual.

It matters not that a computer be binary or even electrical. If a computer were made entirely of analog mechanical parts, it would still add, subtract, multiply, divide. Amazing the power, mythology, and complexity born of such mind-numbingly simple building blocks.

What is a computer? A process perhaps, a connection of communicating elements. Given this definition, then static schematics, flow charts, or a recipe for pasta may be more connected to the digital design than an AutoCAD animation.

History has shown that work in emerging media first adopts the concepts and content of preexisting mediums before entirely new work based in and of the new medium arise. MIT’s David Thorburn calls this phenomenon the “horseless buggy principle.” In essence, the horseless buggy principle reminds us that there was no reason that the first motorized vehicles should look like horse-drawn carriages. The engineers of these early cars adopted forms from transportation that had come before as opposed to designing entirely new vehicles based around the design constraints of the new technology.

Thorburn points out that time and again as media arise, the first step in their acceptance is this assimilation of previous techniques. The first book printed on Gutenberg’s printing press was a bible. Cervantes’ Don Quixote defined a new literary tradition, the novel, which existed only because of the printing press and could not have come before it. The first films were essentially theatre plays shot as though one were a spectator in the audience. The computational medium is still in the early, adoptive phase of evolution. [Thorburn, 1998]

Thus far, design on computers has sought to mimic existing form-making techniques. We present text on a computer monitor as if it were paper. We present movies on a monitor as if it were a television. We design buildings on a computer as if it were a drafting table: plan, elevation, perspective, etc.

Teaching design on computers is commonly thought of as detailing the current version of the latest commercial software. As long as this is the case, design
on computers will (quite rightfully) continue to get little respect from those designers using more traditional design methods. How can we find the "core" of this medium when faced with the constant onslaught of operating system upgrades and version 11.2 of software Y83?

If a new digital design is to arise, we must develop teaching techniques in tune with the basic qualities of the medium. The new digital design is a simultaneous experience of vision, hearing and communication. We now have the ability to communicate interactively with constantly shifting pixels and audio speakers. However, to fully control these devices and create a new understanding of light, space and motion on the computer one must depart from pre-existing tools and preset interactions. This requires new methods to evolve to explain and express the new design process. This paper proposes one such method.

OVERVIEW
DIGITAL SKETCH was an attempt to create a foundation course in basic form-making for the digital medium for students with little to no computer experience. The workshop took place over the course of two weeks in September, 1998 at Designskolen Kolding, Denmark. Designskolen Kolding is a five-year college of design with departments in graphic design, illustration, fashion design, industrial design, ceramics, textile design, and interactive multimedia. Of the 14 students participating in the workshop, 10 were second-year design students and 4 were in the fourth year.

The goal of this workshop was to examine the design process on the computer: how the computer thinks and how, by understanding the computer's processes, we can teach the computer to do our bidding. We engaged in the core issues of the computer design process itself and tried to steer clear of interface fashion.

Our hope was that by revealing some of the unique characteristics of the digital medium, we might develop new design processes in tune with this medium.

For DIGITAL SKETCH, we tried to demystify the process of controlling the computer. We took as our underlying principle the idea that the computer medium may be thought of as a very stupid person.

If we tell another person what to do, we are in fact programming them. The computer works in a similar manner. It merely functions much faster. To use the computer as a means of interactive expression, we must learn how to phrase our desires very explicitly so that it does just what we want.

The master of design for the digital medium is able to clearly explain his or her design as process. Just as people remain the same through human generations, in all likelihood this method will hold true through computer generations (though the semantics may change).

SKETCHING
“To sketch” means to draw, to plan, to play. Sketching occupies such a central place in the process of design that it has become almost sacred: sketching as the first artifact of an idea, sketching as the continuing refinement of an original concept, sketchbook as the artist’s constant companion, emotional repository, and biographer’s documentation. In the context of design, sketching is almost always assumed to take place with a pencil and paper or at least some physical process.

In the DIGITAL SKETCH workshop we studied the meanings of the term “sketch” as it applies to the design process on the computer:
1. We examined the transformation of the line as it leaves the physical medium and enters the digital medium
2. We analyzed the digital computer as a method for planning, testing, and playing with aesthetic concepts

WORK
Physical Process
For the first assignment, the students were asked to make a free sketch on paper. The students were required to use black ink and the primary visual element of the drawing should be the line. The main concerns of the sketch should be motion, interactivity, and process. If the sketch could spring to life on the page, how would one play with it? The students were asked to examine their own process in making the sketch.
Figure 1: First sketches with pen and paper by Espen Moe.
Figure 2: First sketches with pen and paper by Tania Hjorting.
Digital as Physical Process
For the second assignment, we enacted our hypothesis that the computer medium may be thought of as a very stupid person. The students were again asked to make a sketch on paper. However, this sketch must also include a text "recipe." The recipe should allow another person to redraw the sketch accurately. The recipe should assume that the reader knows nothing about drawing and has no knowledge beyond that which he or she is explicitly directed to do. In other words, “pick up the pen,” “put down the pen in the far lower right-hand corner of the paper,” or “draw a straight vertical line 2.5 centimeters long upwards” would be considered within the grasp of the reader of the text recipe. “Draw tiger” would not. In other words, the students were required to not only come up with a composition, but to invent a semantic system for reconstructing the drawing.

As a means of presenting the finished assignments during the following class, we handed each completed recipe to a student unfamiliar with the final drawing. This student was then asked to go to a whiteboard and make a drawing by following the directions detailed in the recipe (without looking at the expected result).

The students expressed that this was a very challenging assignment. In many cases the constraints imposed by creating the text recipe led to a simplification of the final drawing when compared to the first free, physical sketches.

It is interesting to note that many of the text solutions used the same techniques as low-level computer code, such as memory, repetition, iteration, and mathematical operations. This occurred in spite of the fact that none of the students had any previous knowledge of computer programming. They reached these results out of necessity to explain their desires explicitly to another person. This may be seen as a type of validation of our original hypothesis concerning the nature of the computer medium.
Figure 3: Second sketch including text "recipe" by Espen Moe.

Figure 4: Second sketch including text "recipe" by Tania Hjorting
Digital Process
As a logical continuation of the previous assignment, we set about to create our own language for working with the computer. We used the commands developed in the previous exercise for describing a drawing to another person as the basis for the language. We first adopted a grid such as the one arranged by Tania (Figure 4). As several students had the command "draw line ..." of some kind in their recipes in the previous assignment, we chose this as our first command. A Macintosh application was constructed that could interpret our language.

The students entered their digital recipe in a text window in the DIGITAL SKETCH application environment. By clicking on the bar at the base of the text window, they could see the result of their recipe in the square, "drawing" window at the center of the screen. The "drawline" command takes four parameters corresponding to the horizontal and vertical positions of the beginning and end points of the line on the grid. In addition, our interpreter could understand the simple algebraic operations: addition, subtraction, multiplication, and division. Finally, by typing in an “x” or “y” as one of the parameters of the “drawline” command, the current horizontal or vertical position of the mouse would be substituted. In this way, by moving around the mouse the students could see the direct result of changing parameters on their drawing; the drawings then have the potential to bend and transform based upon a user's movements.

Figure 5: The DIGITAL SKETCH digital process application environment.

The students were asked to present a free expression on the computer using our language for the following day’s class. Surprisingly, the students reported little apprehension typing in text as a method for sketching out their designs. When compared with the previous assignment, this process seemed much easier.

Over the course of the next three days, we appended several additional commands to our language, all of which were pulled from the text recipes from assignment 2: "draw circle," "fill circle," and "draw thick line." Aside from these
additions, the language remained fundamentally unchanged through the end of the workshop.

For the final assignment the students were asked to create a completed composition using our DIGITAL SKETCH language. The purpose of the two previous sketches was free exploration in the digital medium. In contrast, for this final sketch the students should demonstrate complete control over the set of commands they employ. Several students noted that the digital design process then began to feel like “math” when they were asked to understand the mathematical techniques they used. Prior to this stage, many of the students had inserted +, -, *, or / signs through trial and error, not caring about the numerical result but focussing instead on the affect these symbols had on their composition.

For their final presentations, the students crafted elegant, interactive compositions.

Figure 6: Snapshots from Espen Moe's final interactive composition.

Figure 7: Snapshots from Tania Hjorting's final interactive composition.

Figure 8: Snapshots from Claus Kristensen's final interactive composition.
TALKS
To frame the subject matter of the course and outline a conceptual base to the assigned projects, a series of talks were given:

Talk 1: Why Computer?
In this talk we introduce the fundamental question concerning creation for the digital medium: Why should one endeavor to create on the computer? Other, more traditional mediums for expression seem to work so well and have established theory, techniques and methodologies. What should we really concern ourselves with? Should we trust terms such as "interactivity," "multimedia," "new media," "virtual reality," etc.? Where can we find our joy in making for the digital medium?

Talk 2: Computer Construction
In this talk we concern ourselves with the physical construction of the computer medium. What is a computer in terms of its physical structure? We live in a physical world. How does the computer medium exist in our world? How can we communicate to it and how can it affect our senses?

Talk 3: Performing Machines
Interactive art was around long before the computer. Here we review some of the many artistic experiments in which machines communicate with one another and/or with an audience. In this way we might understand some of the basic possibilities and limitations of building performing machines.

Talk 4: Metaphysical Digital Medium
Biological signals are received, transmitted, amplified, or reduced by each species according to its senses. Man has both wide and limited facilities for accepting and transmitting signals and can learn a great number of signs by which he manages his day-to-day business. Man uses these signs to regulate his functioning and conduct. In addition, man has the unique ability to transform and reinterpret symbols into pictures, sounds, sculptures, and retransmit these symbols for further recognition by other humans. This may be thought of as "information processing," a capacity also shared by the man-made creation of computers. In this talk we review the history of information processing. [Kepes, 1966]

Talk 5: Processing Art
Since the dawn of the modern movement in the 1920's, artists have transformed information and processes into form. Many of these same artists sought to create works that could be mass-produced and still remain true to the original artist, clearly a task of utmost importance for creations on computers. In this talk we review a limited selection of these great works.

Talk 6: History of Computer Expression
It often seems that expression on computers is without a history. It appears to be so new. Yet the modern computer has been around for 30 years and artists and designers have attempted to make works on and for this machine for at least as long. How did we get to where we are today?
FUTURE EXTENSIONS
The DIGITAL SKETCH workshop is the foundation for a design methodology in tune with computation. From this beginning point we must explore all possible branches of expression related to the digital. We must develop a complete curriculum for understanding design in the digital medium.

Figure 9: Prototype three-dimensional interactive sketch. Original work by Espen Moe.

One of the most challenging fields in the computational medium is the three-dimensional digital sketch. Here we make an initial attempt to surmount traditional approaches by transforming the two-dimensional sketches from the DIGITAL SKETCH workshop into three dimensions. This was accomplished by creating custom software in OpenGL that reads in the text files created during the course of the original, two-dimensional workshop and reconstructs these creations as interactive three-dimensional sculptures. The first of the images in Figure 9 is a snapshot from Espen Moe's final project. The other three are snapshots from the live, three-dimensional version of Espen's creation.

Figure 10: Prototype three-dimensional interactive sketch. Original work by Claus Kristensen.

As with Espen's spider, in Figure 10 we have transformed Claus Kristensen's final project, 'Ping,' into a three-dimensional interactive construction.

In January 1999 a new workshop at Designskolen Kolding was held entitled "the digital/physical border." In this course we employed the same straightforward methodology as the DIGITAL SKETCH workshop, though in this case the medium was the interactive physical and sensory as opposed to purely interactive graphics. We built a series of "reactive spaces," full-scale, real spaces that reacted to a person or people mediated by a computer. Here we examined the input and output and attempted to develop a greater connection to the participant's whole body, not just their eyes.
ACKNOWLEDGEMENTS
This workshop was a collaboration between Reed Kram, the functional posse: Annika Nyström, Jesper Padkjaer, Issa “belly” Kram, and the following students of DK: Sidsel Busck, Tania Hjorting, Pia Jensen, Jörgen Skogmo, Espen Moe, Begitte Andersen, Mette Harrestrup, Ulrika Christiansen, Tatiana Pedersen, Martin Brosböl, Claus Kristensen, Martin Pihl, Jakob Trägårndh, and Signe Laursen. Much of the teaching herein is the direct descendent of Professor John Maeda and the ACG of the Massachusetts Institute of Technology.

REFERENCES
THE ELECTRONIC COMMUNICATION AS A PART OF CAAD EDUCATIONAL PROCESS

AUTHORS
Mirjana DEVETAKOVIC
Milan RADOJEVIC
Faculty of Architecture
University of Belgrade
Bulevar revolucije 73/2
11000 Belgrade
Yugoslavia
mirjana@arh.arh.bg.ac.yu

ABSTRACT
Considering demands of contemporary architectural practice to shift spatial and cultural barriers and became more global and more creative, this paper analyses the role of electronic communication within the process of CAAD (Computer Aided Architectural Design) education. After explaining Virtual Design Studio phenomena, represented by several worldwide university projects, this paper focuses on the reflection of those projects in rethinking the CAAD education approach at the Faculty of Architecture, University of Belgrade. The case illustrating the problem is The Virtual Group activity within the Course "The basics of Computer Application in Architecture". Some examples of student work are given as well as several conclusions based on two-year experience.
THE ELECTRONIC COMMUNICATION AS A PART OF CAAD EDUCATIONAL PROCESS

Introduction
Information technologies and telecommunications are involved in almost every human activity. With its most recent achievements and their application, those technologies significantly characterize the last decades of this century. Nowadays, virtual teams exist in many disciplines that need communication between remote participants. The most important fields in virtual communication are medicine, education, electronic commerce, science, design etc. The process of designing and constructing a building gathers the large number of collaborators, either architects or other engineers, technicians, artists, economists, etc. Coordination of their activities and information exchange between them was always the important preposition for operative, efficient collaboration of design team. As some theoreticians have been anticipated, the decade of the 90’s brings the technological movement in the field of CAD.

This paper came as an outcome of two parallel activities: forming a concept of spatially distributed architectural practice and development of educational process in the field of computer application in architecture.

EAO - European Architectural Office
The idea of spatially distributed architectural practice was born in 1996, when the Belgian architectural group EAO - European Architectural Office, established its departments in Belgrade (Yugoslavia) and Lisbon (Portugal). In that way originated EAO-BE, EAO-YU and EAO-PT. Conceptualizing the system of collaboration in architectural design over large distances, we remarked the importance of the electronic communication, based on Internet services, as one of the most significant support tool (Radojevic et al. 1996). Inside this multinational, multicultural and multilingual environment, the wide range of technical and organizational aspects of this collaboration model has been tested.

Figure 1 explains the sense of spatially distributed design studio idea. Computers on the left side represent the electronic design studio, equipped with all hardware and software necessary for design process. We may suppose that this studio has been located somewhere in Europe. People that have been appearing on the right side of the picture represent a managing team that travel over the world and make contracts on the global market. The man above, superior directing with his hand, has been situated on the one of construction sites in the world, for example in Siberia.

1 "While the CAD/CAM field has come a long way in four decades thus far, its future certainly holds many challenges... It is anticipated that new design and manufacturing algorithms and capabilities will became available. These applications will be supported by better and faster computing hardware, and efficient networking and communication software.” (Zeid, 1991).
Figure 1: Spatially distributed design studio.

As we can see, the structure of collaborators working on an architectural project is complex, multidisciplinary. Every participant operates as a design team member. For us to realize this process we can use the concept of virtual studio, considering application of modern electronic communication.

**VDS - Virtual Design Studio**

Parallel with the activities connected with architectural practice, we have explored the similar experiences from different worldwide university projects (Devetakovic 1997). The internationalization of design process manifested via numerous university projects has been continually appearing in period 1992 - 1997, commonly titled VDS - Virtual Design Studio. At the beginning the most important participants have been American universities, but later a large number of architecture students from universities all over the world took part in VDS projects (Maher et al. 1996 a). They had opportunity to participate in spatially distributed design process, collaborating with colleagues from other countries or continents, other cultures and different linguistic areas. We have been involved in VDS activities trough WWW since 1996, when our country had been connected on Internet.

The appearance of Virtual Design Studio project in early 90’s was one of most interesting challenges in contemporary architectural education. With the respect to all of its numerous participants, we think that the heralds of VDS idea came from American MIT, Canadian UBC, Australian USYD, Swiss NTH and Hong Kong UHK (Maher et al. 1996 a). But, in our research in domain of VDS we had to consider, not only the most important projects, but also their remarkable reflections in developing countries like those in Slovakia (Kosco 1997), Poland, etc.

The history of VDS was theme of one master thesis and several published papers, where we made attempt to discover the significant stages of VDS development and the principles of its conceptualization. But most of all we wanted to estimate our possibilities to work on such collaboration principles and to propose some projects.
The Electronic Communication as a Part of CAAD Educational Process

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<tr>
<th>ILLUSTRATION</th>
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Table 1: The overview of VDS projects in the period 1992 – 1998.

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Table 2: The electronic communication tools used in VDS projects (the darkest is the most important tool within particular project).

The Virtual Class '97/98

Inspired by VDS projects, but considering the fact that we still didn't have certain technical conditions to participate in some of ongoing VDS projects, we have decided to start with one kind of "preparative" program. While teaching "Basics of computer application in architecture", we have established a "Virtual class" consisting particularly of students, which already had their own personal computers. The virtual class worked for the last two semesters ('97/98), e.g. 28 weeks. During that time students had to become
familiar with basics of electronic communication and had to explore some particular problems of its application in architecture. In the first semester students of our virtual group had two hours weekly in our CAAD Lab to meet their teacher, to see each other and to improve their knowledge in electronic communication (using of e-mail, ftp, Web browsing etc.). In the second semester they hadn’t reserved a special time in our CAAD Laboratory. They had to communicate with their teacher and with other colleagues only electronically from their own PCs.

Assignments:

Introduction – the different services of Internet
• Begin with e-mail correspondence (inside the CAAD Lab and from home)
• Make the mailing list of all participants and filter messages coming from the members of virtual group
• Write a CV in Serbian and English language
WWW presentations in architecture
• Browse architectural resources on Internet and collect several WWW presentations of architects or architectural teams round the world
• Make your own WWW presentation
Animated components of WWW presentations
• Find the examples of animated GIF’s and make a collection
• Discuss the role of animated GIF in architectural subject representation
• Make your own animated GIF treating dynamic elements of architectural objects
Web based representation of spatial forms
• Make a 3D spatial composition of cubes and make renderings of it.
• Find the possibilities to insert representation of your composition in existing WWW presentation of your work

The teaching was supported by Web-based brief treating different subjects of informatics applied in architecture. After this experimental work we consider this group of students well prepared to participate in VDS project, either in our academic area, or in some international projects. The explained program was an important experience for teacher too, because there were many specific demands, more engagement and lot of differences, especially in the second semester - the period of "real" virtual communication. The results of this program are completed by several Web presentations. Some examples are shown as an illustration on Figure.
The Electronic Communication as a Part of CAAD Educational Process

263

Figure 2: The Virtual Class, different approaches to Web-based self-presentation.

The Ongoing Virtual Class '98/'99

In the academic year '98/'99 we decided to continue special "Virtual Class" programs enriched with some new aspects in using Internet based electronic communication within the CAAD teaching.

The small and specific linguistic areas like ours haven't the possibility to supply the professionals in various fields with all necessary and most recent publications. This is the case of our country. On the other hand, nowadays Internet offers a wide range of resources for on-line education, particularly in domain of applied information technology. Those courses we can find on the Web, either within the academic networks, as a support of software producers, or as some efforts of independent professionals or professional groups. In our ongoing "Virtual Class" project we decided to include some new potentials of Internet based electronic communication:

• On-line courses
• On-line reading

Instead to make a composition of some given elements and to represent it by inserting pictures and CAD drawings in Web presentation, in this program students have to learn the basics of VRML (Virtual Reality Modeling Language) and to make an example of virtual world. For that purpose they have to use one or several VRML courses available on the Web.

The assignments for this year is enriched with the next contents: VRML - The World of Virtual Reality
• Choose one of the offered Web based VRML tutorial and try to become familiar with the basic technique of Virtual Reality
• Using the VRML create an object in an existing virtual space
• WWW based publications
• Read the Mitchell’s City of Bits available on Internet (Mitchell 1995) and choose the chapter to discuss with colleagues
• Find the architectural journals on the Web and recommend it to other colleagues.
• Internet based collaborative work on final presentation
• Gather all results in one WWW presentation of the virtual group (available on the address: http://www.arh.bg.ac.yu/mirjana/informatika)
• Vote for the best presentation inside the virtual group
• Discuss the results of virtual group experiment

Conclusions
Realizing the large potential of electronic communication in architectural design based on Internet services, we decided to include this aspect of collaboration, establishing special group of students, called "The Virtual Group" on the course "The basics of computer application in Architecture", at the Faculty of Architecture, University of Belgrade. The participants in this particular group were selected considering next criteria:
• owning a personal computer with possibility to connect on Internet
• Certain previous knowledge of the standard program prepared for the rest of students: Windows, MS Office, CAD (AutoCAD, ArchiCAD, Allplan, Arch +...). During the last two years in the programs of "The Virtual Group" participated over 30 students. The program has been evolved during the time and covered next fields:
• Internet based services
• Html as a media for representation of architectural information
• On-line education
All the subjects have been elaborated by developing an individual, professional Web presentation for each member, as well as the particular design team and the entire group. The program is still active and has been realizing on three ways:
• by direct communication in the studio
• by asynchronous communication, via e-mail
• by exercises of synchronous electronic communication
The results of two-year experience of working with "Virtual groups" we would like to include in our standard teaching program as well as in our practice within EAO and in some continued education courses. This program prepares students and professionals, not only to use computers to design and represent their ideas, but also to be able to communicate with other professionals and to become competitive partners in global design society.

References

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2 This stage of program has started at the end of February 1999. The brief is inspired by the exercise description for announced Workshop on the 2nd AVOCAAD Conference.


THE WEB TO SUPPORT CREATIVE DESIGN IN ARCHITECTURE

AUTHORS
R. Corrao
G. Fulantelli
Italian National Research Council
Institute for Educational and Training Technologies
Italy

ABSTRACT

The use of the web in a didactic context appears to be extremely meaningful and effective. In Architecture, the web has huge potential: among others, it has the ability to gather an enormous amount of information, and the ability to create an active learning environment, one which affords the learner opportunities to engage and think.

The paper reports on a Web Based Instruction (WBI) system developed at the Italian National Research Council - Institute for Educational and Training Technologies- to support design activities for students of the Italian Faculty of Architecture and Civil Engineering.

Original features of the system allow students to study and design in an effective way. Specifically, a particular set of “virtual stationery items” has been implemented and integrated in the system to help students, enrolled on on-line courses, to mimic important traditional study activities, still gaining all the advantages of using the Web. These tools are integrated with communication tools in the same learning environment.

A very important feature of the WBI system is that authorised users can enrich the information network in the system, by adding new pages and new links.

In the paper we report on the structure of the system, with particular focus on the information domain. Some of the “working tools” which allow users to simulate traditional study activities and the hypertext extension mechanism are also described.
THE WEB TO SUPPORT CREATIVE DESIGN IN ARCHITECTURE

Introduction
The use of the computer in Architecture is now an established fact. The draft board has definitely been replaced by the computerized graphic station (computer, plotter, scanner, graphic tablet) so much so that is difficult to find a professional study without such equipment. There is still a widely held opinion, however, that "representing" a project of architecture through the use of these tools is enough to guarantee an acceptable qualitative level of the product (building or urban area).
Actually in these quite common cases the computer is not used to "control" the process of designing, but only to formalize its final results; these results are often the outcome of considerations that leave out intermediary evaluations based on new technologies.
The planetary spread of new technologies and the whirlwind development of software packages for assisted design, increasingly considered to be powerful, effective, easy-to-use "intelligence integrator", has led to a radical revision of the classical ways of designing.
The idea that the computer can also support the phases which are preparatory to the real project is becoming more common even among the professionals with less expertise; in fact, the project is founded on the acquisition of the empirical data which the project must consider, by analyzing previous experiences, searching for the technical documentation, studying comparable formal solutions, and so on. All these activities can be supported by the New Technologies. In this context, the telematic communication tools are proving to be particularly strategic.
Taking into account the above considerations, we have developed a Web-Based Instruction system to support the students of the Italian faculties of Architecture and Building Engineering in the definition of projects that can concern either single buildings or whole parts of city. The didactic approach to the question arises from the conviction that the knowledge of the potential offered by new technologies in the field of architecture should be fostered from an undergraduate level, thus trying to train architects who are sensitive to the problems related to a new approach to the project. The use of the web in a didactic context appears to be extremely meaningful and effective; in the specific field of application, the web has huge potential: among others, it has the ability to gather an enormous amount of information which is necessary in Architecture, and the ability to create an active learning environment, one which affords the learner opportunities to engage and think [Hill, 1997]. In particular, creative thinking, which is central for architects, can be supported by the Web.
The system which has been developed tries to make the most of the opportunities offered by the Web. To this end, the system allows users to manipulate the information collected in the web pages of the "Analysis Area" by using particular tools and to perform collaborative study activities on the specific themes of the on-line didactic modules. These possibilities offered by the system confirm that "...the "Web" is not just a metaphor, for there truly is an interconnected network of individuals, institutions and organizations, around the world, opening up new possibilities for design, planning and information sharing in cyberspace..." [Ervin, 1996].
The system and its work areas

New Information and Communication Technologies can support the teaching of disciplines such as Architectural Design and Planning which are traditionally based on the study of past experiences, and which are characterised by a very subjective element. This subjective element is the result of the designer’s personal sensitivity, his/her cultural background and, finally, his/her ability to manage all the different types of information that contribute to the definition of a project, at the scale of buildings, landscapes and urban forms.

For this reason, the hypermedia system that we have developed is aimed at supporting the students, enrolled on on-line courses, from the beginning of the design process.

The system is organized in two “work areas” respectively named “Analysis Area” and “Design Area”. The “Analysis Area” organizes -in a hypertextual way- the “external” and “objective” information necessary for the design (data on the town and on particular areas, the context for a new building, building regulations, administrative laws, formal and bibliography references, and so on). The “Design Area” provides Web-based synchronous and asynchronous communication tools (e-mail, electronic discussion forums, video-conference system, chatting) and includes tools to support the “control” of the project (virtual galleries, shared blackboard).

The two work areas are related to the most important phases of the conceptual designing process. These phases usually consist in searching for information and transforming it into the project that should satisfy the expectations of the final users.

Actually, one of the major features of the system is the integration of these initial moments, thus allowing students to better understand the unique character of designing activities. Through the use of specific tools, the user has the possibility of alternating search activities and real planning, comparing his/her own results with those of other users and with the teachers of the on-line courses.

The information domain

The system can be used to support the redefinition of any part of the city which needs spatial and functional refurbishment or of some areas on the border of the city still lacking a real identity. For this reason information in the system is at the scale of landscape, city and building too. As a case study, we have chosen the city of Palermo and, in particular, its sea front, in view of its future redevelopment.

Central to the design of the system has been the definition of the information model; this is extremely important when designing dynamically scalable hypertext systems. We have imposed an a-priori organization of information, in a way that new nodes can be immediately classified in any pre-defined category (and added to the right place in the network). This is a condition necessary to guarantee a consistent growth of an on-line informative hypertextual network. It should be noted that a precise and rigorously defined model of the information is not a limit to the hypertext flexibility, rather it represents a “sine-qua-non” condition for its scalability and management.

The information domain reflects the methods of access to the information. Access to the Analysis Area has been provided according to three different reading keys specific to the information domain. Users can get access to the
pages through three different Indexes which refer to three different “categories” of information: chronological, topographical and typological. These three information categories have been used to classify the hypertext nodes and they divide the information space into three logical sub-domains; each sub-domain corresponds to one of the three access methods, and can therefore be entered through a different index. Each node is put into a specific “class” belonging to a category; a single node can be classified according to multiple access criteria and, as a consequence, it can belong to several classes of different categories. In order to obtain a more refined classification, categories have been in turn divided into sub-categories.

Since the user can choose how to enter the Analysis Area, depending on his/her interests and the different aims of his/her research activities, different navigation paths are available through the nodes of the hypertext collected in the different sub-domains.

It is possible to conduct the research from pages that describe the development of the city of Palermo over the centuries (chronological access), or the present state of some part of the city in which it is possible to operate with an architectural project -e.g. the sea front- (topographical access), or the condition of particular buildings, streets, squares of the city (typological access). For example, through the chronological index the user can access the historical period in which the research must be carried out and, afterwards, the class in which the subject of the research is collected (e.g. historical period: Palermo in the XVI century; street: Via Maqueda).

In particular, through the Chronological Index, the users have access to an animation based on an ideogram that chronologically represents the growth of the city of Palermo and that automatically activates a series of icons. These icons, which represent historical plans showing the modifications of the urban structure over the centuries, are real access keys to the information. By selecting an icon, that represents a "class" of the Chronological Index, users can choose the subject of the research by consulting a list that shows all the documents referring to that particular class.

The Topographical Index allows users to have access to a map of the city divided into different areas. By clicking on each area -the sea front, in particular- the users have access to a map on a larger graphical scale. These areas represent the "sub-categories" of the Topographical Index. Starting from these areas users can activate the links to recall the specific web pages, related to the particular area of the map. These pages may deal with the history of particular buildings of the city (or streets, or squares, and so on). Consequently, some pages can be collected according to all the three indexes; it will be easier for the users to search for specific information related to a particular building (or street, and so forth) of the city in a historical period, since it is reachable through all the three indexing mechanisms.

**Working with the information: the “Licence Bar” and the “Tools Bar”**.

A "Licence Bar” allows system known users to add new pages and new links to the information base, so that the hypermedia network can be extended by the users. They can add text, images, drawings and movies by simply filling a form which is recalled through the New Page tool of the Licence Bar; during this operation the user can decide to create links to other pages (in the system or external web pages).

Information nodes which are added by the users can be easily classified and, consequently, located by other users. In fact, when users create a new page,
the system asks them to identify the class (or classes) the new page belongs to. Users can select one or more classes the new page belong to, and the page will be listed in the navigational indexes. Otherwise, the user can ignore classification of the page, which will be automatically linked to the page the user was visiting when the new page was created. In this latter case, the page will not be listed in the indexes, even if it is still classified in the same classes as the original page; it is treated as an appendix page.

The "Tools Bar" allows users to handle the information in the Analysis Area, to carry out operations on the information pages to maximize the learning process, and to recognize all the phases of knowledge acquisition. Changes to the page content performed with these tools are known only to the user who makes the modification. The philosophy of these tools is, in fact, the provision of a mechanism for individual study strategies.

The "Tools Bar" represents a particular set of "virtual stationery items" students can use to mimic traditional study activities while working on the Web.

For example, the "Marker" tool allows students to highlight images or parts of the text on the pages; the selected parts remain highlighted for the duration of the on-line module the student is registered with. During first reading, the user can "mark" each page of the system s/he considers relevant to his/her study by using the "Page-marker" tool; the user can navigate back to the marked pages through the "Iter" tool to study these pages in more detail (Unlike the "history" tool available in most of the commercial browsers, the "Iter" tool keeps track of the operation performed by the user on the pages). The "Note" tool allows user to add notes, reference-marks and other information to the text of a page. The notes, which are for the private use of the user who created them, remain "attached" to the pages from one on-line work session to another. The tool "Iter" highlights the presence of notes on the pages. The "Kit bag" tool represents a kind of catalogue that users carry with them during navigation through the Analysis Area and where they store pieces of information collected on this way around; furthermore, users carry the "Kit bag" with them in the Design Area together with the “Note Book” tool, where they can write down -during navigation- reflections, critical notes, and so on.

These tools are always connected to the pages, if the users are known by the system, together with a mail box and a chat room that it is possible to activate along the navigation route through the web pages of the Analysis Area (Fig. 1 – Screenshot of the system).

It should be noted that the system allows operations to be carried out using these tools depending on the type of user. In fact, even if the Analysis Area is public, the "privilege" to use these tools to manipulate the information of the pages (by the Tools Bar) and to extend the hypertextual net (by the Licence Bar) is granted only to the system known users. We have distinguished 5 categories of users and provided different access privileges for each of them: the system designers, the on-line tutors and the system administrators, that together represent the first category, teachers, students, expert guests, guests. From the first to the last category the privileges are progressively reduced. However, the privileges can be established every time a new on-line course is started, according to the specific requirements of the course.
The tools of the Design Area
The Design Area is directly aimed at some important phases of the design process; it provides Web-based synchronous and asynchronous communication tools (e-mail, electronic discussion forums, video-conference system, chatting) and includes tools to support the "control" of the project (virtual galleries, shared blackboard). This area does not contain design software, such as CAD software, even if it allows users to configure direct links to their own software. In fact, the computer-supported design and rendering activities are performed by the students on their computers (or on the computers they can use at university laboratories). Communication and integration between the different projects are guaranteed by the standard format of the resulting files. The "Shared Blackboard" and The "Virtual Gallery" can specifically promote teaching and learning of Architecture through the Net. In particular, by using these tools, students have the opportunity to publish their projects ("Virtual Gallery") and correct them through the "Shared Blackboard" in which teachers can graphically suggest corrections or design solutions: in this way, students have the opportunity to assess the progress of their own design activity, to reflect on their work and adjust it according to feedback from teachers, tutors and other students. Students gain access to the Design Area through their Home Page, corresponding to a personalized access point to the system; from this page, in fact, they can enter the Analysis Area, or have access to all the available communication and working tools. Finally they can read the assignments for the course and find out about new information added to the system by other users (students or experts) from their last connection (new pages in the Analysis Area, new projects in the Virtual Galleries, and so on) (Fig. 2 – The student's Homepage).

Conclusions
In Web-Based Instruction (WBI) environments, the generic advantages of the web are exploited so to activate important cognitive and meta-cognitive processes which promote active learning. One of the most interesting aspects along these lines concerns the collaborative activities that are facilitated by the communication tools and the sharing of information integrated in a WBI environment. In fact, the Web offers extensive opportunities for collaboration and cooperative learning. Of the learning mechanisms that are possible on the Web, creative thinking and problem-based learning are extremely important in the case of the design in Architecture. In fact architectural design is an extreme case of project-based learning, in which the project to be developed is both the didactic objective and the means through which it is possible to activate specific strategies to learn how to design. The Web has proved to be extremely effective in supporting such activities [Collis 1997]. Consequently, the WBI environments can support the preparatory phases of the project in Architecture, including some extremely important creative phases. The structure of the system allows users to perform different types of activities in the same web environment. The operations that the authorized users can
carry out on the web pages of the Analysis Area, through the “Working tools” of the “Tools Bar”, represent an important feature of the system which has been developed improving cognitive access to the WBI system and supporting flexible and effective study activities.

It should be noted that some of the activities described could already be performed by using features of the browsers and of the most popular operating systems. However, these solutions are unsatisfactory because the mechanisms are not integrated into a single environment, they are usually separated from the learning context and require a cognitive overload on the part of the learner.

On the contrary, the developed WBI system does not require any particular cognitive overload on the part of the learner, only producing an intense level of cultural competition between the students of Architecture and Civil Engineering.

Finally, there is a practical reason which leads us to consider using New Technologies at university level, which is perfectly summed up by A.J. Romiszowski [Romiszowski 1997]: "new technologies, on the one hand, offer us tools with which to deal with the new challenges that a changing society or workplace presents and, on the other hand, those same technologies actually are responsible for the changes that are generating these new and ever changing challenges". Consequently, the competencies that are required by tomorrow’s architects and professionals require efficient and rapid learning of the use of new tools and techniques that are constantly appearing in the job environment; therefore, it is extremely important to introduce the use of new technologies in the future architects’ curricula from their university study.

References


TRANSDUCER:
3D AUDIO-VISUAL FORM-MAKING AS PERFORMANCE

AUTHORS
Reed Kram
Chalmers Medialab
Chalmers Tekniska Högskola
Vasa Hus 4
41296 Göteborg
Sweden
kram@media.mit.edu

John Maeda
MIT Media Laboratory
20 Ames St.
Cambridge, MA
U.S.A.
maeda@media.mit.edu

ABSTRACT
This paper describes Transducer, a prototype digital system for live, audio-
visual performance. Currently the process of editing sounds or crafting three-
dimensional structures on a computer remains a frustratingly rigid process. Current tools for real-time audio or visual construction using computers involve obtuse controls, either heavily GUI'ed or overstylized. Transducer asks one to envision a space where the process of editing and creating on a computer becomes a dynamic performance. The content of this performance may be sufficiently complex to elicit multiple interpretations, but Transducer enforces the notion that the process of creation should itself be a fluid and transparent expression. The system allows a performer to build constructions of sampled audio and computational three-dimensional form simultaneously. Each sound clip is visualized as a “playable” cylinder of sound that can be manipulated both visually and aurally in real-time. The transducer system demonstrates a creative space with equal design detailing at both the construction and performance phase.
Motivation
Currently the process of editing sounds or manipulating three-dimensional structures on a computer remains a frustratingly rigid process. Current tools for real-time audio or visual performance using computers involve obtuse controls, either heavily GUI’ed or overstylized, making it difficult for the audience to understand exactly what the performer is doing. Considerable work has been done in the design of gesture recognition in the manipulation of three dimensional form, particularly by Zeleznik[2]. The most notable aspect of this approach is the sense of comprehensibility that the system appears to have, in spite of its gesture complexity. In the Transducer project we attempt to adapt this approach originally designed for static form-making and test its suitability for use in a performance system.

The intent of this system is not to act as a traditional tool for editing audio, nor as a three-dimensional modeler. Transducer asks one to envision a space where the process of editing and creating on a computer becomes a dynamic performance which an audience can easily comprehend. The content of this performance may be sufficiently complex to elicit multiple interpretations, but Transducer enforces the notion that the process of creation should itself be a fluid and transparent expression.

This type of digital performance is a special type of computer-human interaction where the standard metrics of interface quality do not directly apply. An audience expects something out of the ordinary, immediate, live. We focus on a simple input grammar and a deceivingly simple visual representation as the gateway to the environment. We akin the simple interactive language of Transducer to that of a DeeJay’s mixer, encapsulating the magic of disk-jockey performance with concise visuals that are clearly in tune with the music.

Interface

The performer and audience of the Transducer system view a video projection which illuminates a screen hanging from above and listen to audio from two speakers (Figure 1). The performer acts upon the system with a single-button mouse. There are no menus in the Transducer system. All interface actions occur on cylindrical sound objects.
The system first presents a palette of cylindrical objects (as in the top snapshot of Figure 2). As the user/performer moves his or her mouse over each of the cylinders, he or she hears the sampled sound stream associated with that object.

By clicking the left mouse button while over the object, the user selects the sound object to be manipulated. The palette of objects unfolds and drifts behind the camera (this transition can be seen in Figure 2), the sound associated with the chosen object begins to play, and the selected object moves to the “manipulation zone.” In this area, four types of mouse actions control the sound object as shown in Table 1.

<table>
<thead>
<tr>
<th>Mouse Action</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Click and drag vertically up or down</td>
<td>Increase/decrease sound frequency, increase/decrease height of object</td>
</tr>
<tr>
<td>Click and drag horizontally towards or away from object center</td>
<td>Increase/decrease sound amplitude, move object towards/away from center, increase/decrease object transparency</td>
</tr>
<tr>
<td>Short click on object</td>
<td>Stop playing sound, return object to palette</td>
</tr>
<tr>
<td>Click anywhere not on object</td>
<td>Bring up palette of all sound objects with active sounds visible behind</td>
</tr>
</tbody>
</table>

Table 1: Gestures for Sound Object Manipulation.
Additional sound objects can be previewed and up to 7 sound objects can be brought into the manipulation zone.

In this way a single user or performer is able to build simultaneous visual and audio constructions in real-time. The user can layer and examine interrelationships between multiple, diverse sound sources and corresponding visual forms.
Data abstraction
The form of each object gives clues as to the data (or sound information) contained within. Each of the sound clips is rated along six axes according to the characteristics of the sound stream: jazz factor, ambient factor, speed factor, vocal factor, hip-hop factor, and german-risque factor. Each of the objects has a representative color and size corresponding to the characteristics of the sound stream associated with it.

In addition, the motion of each object is controlled with a unique physics model again based on the qualities of the sound according to our rating system. Thus two objects react differently to user input based on the internal “mass” and “drag” of each, as in Kram/Maeda[1]. This allows for smooth, dynamic reactivity of objects to both user input as well as that of a changing audio source.

Representation
When audible, a given audio source is split into a range of pitches. Each pitch range is represented as a single cylinder. The amplitude of a pitch can be seen in the diameter of its corresponding cylinder. A complete sound stream forms a solid structure of combined cylinders arranged in increasing pitch from bottom to top. The sound structures shift and transform based on the changing audio source.

![Figure 3: Sound object structure.](image)

By parameterizing each aspect of the performance, we can create continuous (rather than discrete) relationships between the different dataspaces (audio and visual). Since our interface to the system is primarily gestural and our primary focus is on the ability to immediately conceptualize expression, we are
not concerned with the precise representation of sound or visual structure. Rather, we are concerned with an acceptable simultaneous approximation of both, able to be realized in real-time. Along these lines, the system makes extensive use of interactive physics algorithms for scene transition and effects.

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USER DEFINED DESIGN GENERATORS - A GRAMMAR EXTENSION OF CAAD SYSTEMS

AUTHORS

Michael Hellgardt
Prinsengracht 151
1015 DR Amsterdam
The Netherlands
106555.1412@compuserve.com

ABSTRACT

A command system for CAAD, +G, is proposed for the definition and application of design grammars. With an emphasis on Aalto and Scharoun is discussed how design observation can be transcribed into rules of a grammar, SAG (Spatium Array Grammar), that reflects space-between structures ubiquitous in the built environment.
§1 A same shape grammar formalism (Stiny, 1980a) has been applied to model a variety of phenomena, such as the Fröbel Baukasten, Palladio villas, F. L. Wright’s prairie houses etc. This fascinating formal machinery (Stiny) can be used to describe particular languages and grammars, machines, that can generate expressions - by hand or computer implementation. But it cannot understand different languages and grammars in relation to each other. This formal machinery is language theory, frozen at the level of description. What is missing is the link to some kind of theory, language theory, given as a system of grammar rules describing not just blind mechanisms of unrelated languages, but a “speakers” competence in various languages and grammars to generate expressions in actual situations of language performance. To establish hierarchies of rules, to compare rules and rule sets of different languages, to investigate rule acquisition by language performance - these are operations of understanding language, their functioning in space and history, their blindness, their openness, etc.

Can a formal machinery, or a machine, understand anything? The paper joins those who say: no. But these people use to add, in one way or another: any new machinery is a challenge to understanding. On that ground competence in architecture - as in any other domain of specialistism, except for the formal sciences - should not be confused with competence in formal design modeling and computer implementation. But the latter, the technology of AI ultimately, can provide tools for a computer supported experimentation with shapes and design rules and grammars - not only for the specialist in formal modeling, but also the ordinary architect without special formal knowledge.

§2 “Words are like pistols, ready for use,” one of the great French writers has declared. The same applies to shapes. A word is “fired” in a linear context, as Chomsky’s most general form of a grammar or rewriting rule resumes:

(1) A → Z/X—Y, where A is realised as Z in a string between X and Y.

Shapes are “fired” in a spatial, 2- or 3-dimensional context. Architectural design and environmental growth applies two main types of shapes. Accordingly we get

(2) Sh → FA Sh, where Sh is a fixed shape, or a parametric shape with one or more parameters bound to functional restrictions, inserted into a context by a function FA, Find Allocation, or

(3) Sh → FA GS, where GS is Generate a parametric Shape with all parameters free.

Shape-rules and shapes are related by indices and parameters. This makes, within restrictions, grammars, shape rules and shapes independant - prior condition of the kind of experimentation claimed above. A shape rule can be called for any shape of a specified category region in different grammar contexts. It evaluates an evolving design, a shape and its parameters.

§3 The furnitured wings of figure 1 result from as many applications of a rule of type (2) as there are functional units prescribed by a brief. Such units may be part of building component taxonomies. Architectural design is largely a
configuration of functional units, occasionally even exclusively - which does not yet mean that ‘form follows function’.

§4 Shapes in (3) are geometric units or mental images, called *leitbild*. For Scharoun, in comparison with Aalto, crystalline leitbilder, as those of the “Gläserne Kette”, were fundamental. Two leitbilder are fundamental in the work of Aalto. One cultural: the amphitheatre, one natural: irregular boundaries, remaining of a pool/trunk/cloud/etc. Figure 3, bottom right, shows that GS in (3) can destruct a leitbild. It marks an approach that underlies many of Aalto’s assembly halls. The curved contours of figure 7 are applications of the pool/trunk/cloud/etc leitbild. Such examples open a discussion of how FA in (3) could be formalised and prescribed by parameters of shapes that can be passed to one or more shape rules.

§5 Design can be modelled as a *concatenation of shape rules*. Search for successful shape rule concatenation can be organised by networks, called Tree Adjoining Design Grammars*, that adjoin trees of the form of (4). The root arcs of this tree address terminal shape rules or shape categories. Shape categories are preterminal if they denote terminal shapes. Otherwise they are nonterminals. The nature of architectural design, and grammar in general, can only be grasped if we include *nonterminal* shapes. Nonterminals call subnetworks for embedded design components which can be of the same kind as a shape rule category (a node) at a higher level. This makes a network recursive. Recursive networks require registers of an evolving design that can be modified and store temporary information for evaluation in various main- and subnetworks. These registers are the context argument, in structured numerical and symbolical form, for all arcs.

![Diagram of Tree Adjoining Design Grammars](image)

§6 A design grammar can be defined by a number of compulsory or selectable shape categories (CSC, SSC) and sequential restrictions, called design rules. Design rule parameters can prescribe restrictions for particular shape categories. Node transition in (4) is blocked by test labels if illegal shape category sequences are encountered. To the extent that these test labels are uniform a TADG can be nondeterministic. In case a not viable combination is encountered search can go back and try another arc: a path option in (4) stored in a path memory when the nodes of a TADG are encoded.

§7 Design performance is more than the application of just one grammar. It experiments with shape vocabularies and syntactic devices that can be part of various grammars and “languages”. Architectural design performance, moreover, often evaluates existing context situations as initial shape, or design. The concept of *parametric shape grammar* (Stiny, 1980a) ignores these aspects. If we want to account for design performance a device is needed that applies grammar knowledge, that is design competence, in a local

* Tree Adjoining Grammars are applied in Natural Language Processing. Not all references and inspirations are specified in this paper.
context of requirements, intentions and context restrictions. Such a device is
called a design generator.
If a grammar contains no SSC's the distinction between design grammar and
generator is senseless. Otherwise a design generator must be defined and
encoded as a network for the CSC's of a grammar selected and a user
specified subset of its SSC's.
A design generator is run with the compulsory argument of a context as initial
shape (which cannot be part of a grammar as it is in (Stiny, 1980a)) and
optional grammar and operational arguments for non-default values. Grammar
arguments are shape parameters and design rule parameters. Operational
arguments are search and representation parameters. Search parameters (c.f.
§11 and 12) prescribe a search mode, exhaustive or some kind of directed
search, and the required additional parameters, for instance goodness criteria.
Representation parameters assign a CAAD system and possibly related
prescriptions for graphic representation.
§8 Grammar and operational devices are the main sections of a design
reasoning system, +G, that can be used as a command system for CAAD
systems for design representation. Design results from a constant exchange
between design performance in practice and observation and design
competence. +G is design competence that supports such an exchange in
computer aided form for users without special formal knowledge. Provided a
shape definition macro is given that controls the connection between shapes
and shape rules, a shape library, possibly related to existing component
libraries, can be extended by such users. The same applies to grammars,
provided a body of shapes and shape rules is given that allows
experimentation outside existing grammars. The development of operational
devices and, presumably, shape rules is the domain of formal modeling. +G
can only result from a permanent exchange between design in practice and
theory, AI research and software development.

\[+G = \{\text{Grammar Knowledge, Operational Devices}\}\]
\[\text{GK} = \{\text{Design Grammars, shape library, shape rule library}\}\]
\[\text{DG} = \{\text{Compulsory Shape Categories, Selectable ShapeCategories, Design Rules}\}\]
\[\text{OD} = \{\text{devices for shape rule concatenation, search, user definitions and the transcription}
\text{of data resulting from design reasoning into CAAD commands}\}\]

§9 We proceed with some observation of design performance, searching for a
grammar frame which is applicable to divergent phenomenae. All expressions
in the shape rules (5) to (28) are nonterminal shape categories, with the
exception of AFM, in (16), MD, in (20) and X, in (21) which are preterminals. (4)
and all grammar rules below, except for (6), (7), (18) and (22) to (28), are in
principle tested by computer implementation.
Imagine n settlers, each of them building a house such that a courtyard results
between the new and the previous house. Such courtyards are called spatium
and such houses extensio. Spatium, in philosophical terms, is more than a
measurable extensio, it is the space of movement, the unknown, the potential
etc. An array of spatium's can be resumed as:
(5) SAD → E S SAD, where SAD is Spatium Array Design, an expression of a
SAG (Spatium Array Grammar), S Spatium and E Extensio. If no n is specified
SAD is endless. Otherwise it is recalled n times with the brief of a settler in life
or symbolically represented form.
§10 Settler₁ has to look if some object in a context given can substitute a previous house (a). If none is found, he must build more than one houses to get a courtyard, a spatium, between them (b), or a house like a shell (like Fiesler's Endless House etc.), that is a more or less hollow extensio (c). For (a) and (c) we can write for E₁ in (5):

(6) E₁ → R, where R is Read natural context (c.f. §16) and

(7) E₁ → HE, where HE is Hollow Extensio.

If we ignore the aspect of being head units in the Salute context, the bottom variants of figure 1 could be produced by a settler of type (b), with the result of n = 2 for (5) and a not empty S for n = 2.

§11 The wings of figure 1 result, among other, from:

(8) E₁ → MBV SAD, where MBV is Make Brief Variants. This means that a number of brief variants is generated first - topological variants of the kind demonstrated by figure 1 - and SAD is restarted with one or more of these variants, depending on the search mode prescribed as a parameter of a design generator. In case exhaustive design is prescribed we get

(9) E₁ → NBV SAD, where NBV is Next Brief Variant and SAD is recalled until all brief variants are addressed.

§12 In case of GA(Genetic Algorithm) directed search we get:

(10) E₁ → RSAD SAD, where RSAD is a Random SAD for a random brief variant and random parameters. This form generates an initial “population” of a specified length with which SAD is restarted as

(11) SAD → IIP, where IIP is Improve Initial Population (an algorithm based on (Kundu, 1996)). The variants with hatched regions (spatium’s) in figure 1 result from such an improvement that couples, to put it simplified, brief variants with right origins, Oᵣ’s. Oᵣ shifts in a field prescribed by (14) and distance- and angle-parameters set as search parameters with the definition of the design generator. Other search parameters are goodness criteria, here the spatium surface and 2 distance values.

§13 With the exception of E₁ as discussed in §10 any Eᵢ in (5) is of the form

(12) Eᵢ → (2) SAD*, where SAD* is a toploop call of SAD discussed in §14, or

(13) Eᵢ → (3) SAD*.

The wings of the variants of figure 1 result from (15). Here FA in (3) is of the form of

(14) FA = FOO, where FOO is Find Origin Outside any extensio in the current registerer. FOO works on the arguments of a reference position and a brief. In §14 and §18 a ‘Find Origin Inside’ is raised.

The upper right corners, Oᵣᵢ, of the variants of figure 1 are such origins, defined in relation to a reference origin, here Oᵣ₀ of a wing already given and an angle, αᵣᵢ. They result from a procedure which is perhaps typical for Scharoun: to organise wings around a central space, simulated as Spatium here, which Scharoun called “Raum der Mitte”. Though organic architecture and Scharoun design are not necessarily oblique-angled, such wings are generally swung in relation to eachother. Perhaps it is only the way of swinging that is Scharoun specific.

GS in (3) in (13) can result from another SAD, another SAG design generator, or from another grammar generating an extensio. The wings of figure 1 result from a Furniture Mat Array (FMA) grammar:

(15) GS → FMA

(16) FMA → AFM₁ ... AFMₙ, where AFM is Attach Furniture Mat, a rule of type (2).
The “kindergarten grammar” underlying the Fröbel (and Lego) building blocks (Stiny, 1980b) is an example of an array system that allows the attachment of blocks to blocks (labelled shapes) in various ways. We can call such rules attach rules. In that view they are not rules of Spatium Array Grammars, but of Array Grammars. They organise the array of units attached to each other with no space in-between. FMA is another array grammar. It evaluates
- attach points resulting from the distribution of objects (for example matjes, furniture mats, a Dutch convention) in boundaries and
- accessibility restrictions defined as parameters (slots) of shape categories.

Figure 1: east part of Hans Scharoun’s ‘Salute’ design (top left); SAG generated variants for a fixed boundary (top centre, Autocad representation); SAG generated variants for head unit (bitmap representation); initial FMA (top right), rejected member of initial population for GA directed search (bottom left), GA improved population (bottom right)

§14 Figure 1 top right, shows an initial FMA-generated configuration for left and right wings with overlaps. In both (12) and (13) the top SAD operator is reactivated in the form of SAD* in order to detect and to adjust such destructive results of new Ei’s. The *-index says that the mechanism is essentially of the same form as (5), but does not create new extensions or spatium’s, but tests and probably re-designs given spatios and extensios by operators E* and S*. As a design toploop, the SAD* operator runs back through a design which means it takes extensios and spatios in reversed order. It is restarted as long as a previous SAD* has been successful, that is a destruction has been encountered and the design register edited:
(17) SAD* → S* E* SAD*

Efficiency oriented architects avoid such toploops. But they can be inevitable. For economic reasons and similar, or - as it appears to be in the work of
architects like Aalto or Scharoun - for the mere sake of design. For Aalto, as will be demonstrated in §18, we can even say such toploops were "programmed" by another option for ‘Find Allocation’ in order to trigger solutions that cannot be achieved otherwise:

(18) $FA = FOI$, where FOI is Find Origin Inside an extensio or part of it.

A design toploop is also called as long as a design contains only preliminarily designed sections. A preliminary elaboration can be prescribed by external conditions, such as stages of realisation. Or it can result from the logic of design itself too: certain solutions emerge only gradually in step by step refined design contexts. A preliminary solution is entered into the register of an evolving design associated with temporary information that prestructures later recursion and refinement.

Finally, design toploops can also serve as global tests without a particular reason. Certain judgements are only possible when a design is visible as a whole. Such toploops are important for architects like Scharoun, often to the lament of customers. “La forme cout cher,” another French writer has declared.

§15 In (5) proceeds as follows:

(19) $S \rightarrow D F$,
(20) $D \rightarrow MD_1 \ldots MD_n$,
(21) $F \rightarrow X_1 \ldots X_n TS$,

where $F$ is a Fill operator for a fill-brief, $MD$ is Make Delimitation, a rule of type (3), and where $X_i$ is an object to be allocated in S and TS Test Spatium

The spatiums of figure 1 result from two types of very simple MD rules. Figure 7, mentioned in §4, shows a more elaborated kind of an ‘attached’ delimitation or boundary.

Shape rule evaluation can be prepared by auxiliary shape rule functions, possibly to be applied repeatedly by shape rules with different shape arguments. For example, such an auxiliary function can elaborate a set of reference points for the tentative allocation of various shape categories in a boundary. (21) can work with such an auxiliary function. Auxiliary functions can work on parameters, a resolution degree for example for the distribution of reference points, which must be set globally for special shape rule types for a whole state space of shape rules to be evaluated.

Spatium is parasitic: it results from extensio. (19) to (21) are rather tools for search - whatever that may be. No design toploop, SAD*, is called at the end of (19), because only an extensio can be destructive.

§16 Only (a) of the three settler types in §10 performs context sensitive design, starting with (6) as initial operation, $E_1$. Context sensitive design is important for entire schools of architecture. Treib (Aalto, 1998) says:

As physical compositions, Aalto’s non-urban buildings tended to divide into two basic groups: concave or convex. The concave schemes reiterated the contours of fissures and valleys- The convex schemes complemented or reinforced rising landforms. And for those sites that lacked potent natural features Aalto constructed his own architectural landscape.

(22) read_context(R)
    construct_context(CSC) complete_context(CC)
We can resume this as a read rule, R, read-context, in tree form. This tree says that a fan of leitbilder is inquired, if some leitbild can be applied in order to elaborate a design as a completion of a natural context. If no leitbild is found to be applicable, or if the initial context register is empty (lacks natural features ...), a first extensio, $E_1$, is constructed as an artificial initial context (CSC) and the read-context operator is restarted with the result as initial context register.

Figure 11 shows a beautiful example of a design resulting from a convex context reading. The building applies vertically the shape of the hill it stands on. An example of the same species shows figure 12. Here the shape of the high rise part follows the isohypses of the site. This horizontal approach is continued in the third dimension in form of a back wall which is inclined in the direction of the slope.

Figure 4 and 5 testify a concave context reading: a mould. The programme is subdivided in various sections which in case of figure 4 are more or less embedded into the mould figure read: an irregular open arc of the leitbild pool/trunk/cloud/etc. Figure 5 is different. It demonstrates that Aalto has also been experimenting with another approach which is rather a contrast- than an apply-approach. In figure 5, which is in line with the executed design, the museum is allocated in essentially only one single block at the bottom of the mould and isolated from the rising slopes that form the mould. It is interesting to observe another contrast case: figure 6. Here the contrasting block is allocated not at the bottom but at the top of a mould context.

We can resume all these observations as two options for a Complete-Context rule, CC in (22):

\[
\begin{align*}
CC & \rightarrow IL_{1,n} \ AL, & \text{where IL is Insert Leitbild and AL Apply Leitbild and} \\
CC & \rightarrow IL_{1,n} \ FCS, & \text{where FCS is Find Contrast Structure.}
\end{align*}
\]

These rules say that a leitbild first is inserted in the context it is read from in order to serve as a reference for a contrast solution, or to be applied to shape a design in one way or another. Figure 9 and 10 can be read as another illustration of the latter. Figure 9 shows a broken line, an obtuse angle, inserted in a site-plan. This could be the result of a context reading. This figure is applied then for the topological distribution of the main brief sections. The result of this first extensio, $E_1$, is not yet a real one, but an auxiliary pattern that prestructures the allocation of extensio’s, $E_i$’s, to follow. In this way figure 10 can be read.

We can also imagine that in a first, probably not even graphically represented step the right part of the obtuse angle was entirely or partially filled by a single global, but already approximately dimensioned grid - or rather a kind of terraced grid, following the slope of the site. If this is justified, we have an example of a preliminary extensio, to be subdivided and refined by later transformations.

Figure 10 also demonstrates how a spatium can emerge in various ways between externsio’s. As a simple array order with no spaces between its parts,
the lower left part, however, appears rather to be an exception from that. In terms of (5) this can be expressed by empty spatiums between externsio’s, which do not block the top mechanism. At closer inspection, this part turns out to be garden architecture.

§17 A peculiar approach to allocate shapes or design sections in a design context belongs to the most salient features of Aalto’s legacy and meets what has been marked as collage or heterotopic.

The top right sketch of figure 3 can be read as a kind of head-allocation, the larger sketch to its left as a kind of angle-allocation: the auditorium is embedded into an angle region: the spatium region resulting from a concave context leitbild, as discussed above. This region could have been empty such that no overlap with some unit already given is possible, or not. The bottom left sketch of figure 2 and, perhaps, the larger right sketch too show that convex angle-allocations are also possible. The lecture hall of figure 8 we can read as an instance of a head-allocation or a convex angle-allocation.

§18 The top left sketch of figure 2 demonstrates, perhaps better than other examples, that such forms of allocation are easily destructive. Here we have a lateral allocation such that the not rectangular library section is allocated at the broadside of the rectangular reference section with the result of an overlap, though not a very large one. Such overlaps are detected by the SAD* toploop called in (12) and (13) after any externsio. The general form of an externsio to be tested and possibly edited, E* in (17), is:

(25) \( E^* \rightarrow \text{FOL EE} \), where FOL is Find OverLap, a test function that recalls itself as long as no overlap (no intersection) is found, and where EE is Edit Extensio.

In the case of the top left sketch of figure 2 there is no previous spatium S, and the first externsio given, the rectangular part of the sketch, is found destructed, as \( E_{\text{found}} \), overlapped by the new not rectangular shaped externsio \( E_{\text{current}} \). There are two possibilities to reconcile such destructions, two options for EE in (25): to edit the current, overlapping externsio (26), or the previous, overlapped one (27). Resulting from the SAD* toploop, both can be edited too. The transformation of the initial FMA layout of figure 1, top right, into not overlapping configurations of the kind of the bottom row of figure 1 can be an example of the first of these alternatives. It can be resumed as:

(26) \( \text{EE} \rightarrow \text{RAU EEC} \), where RAU is ReAllocate Unit, the overlapping unit of FOL, and EEC Edit Extensio Current.

The top left sketch of figure 2 can be interpreted in terms of the second of the two alternatives, a second EE option resulting in a spatium cut out from a destructed externsio.

(27) \( \text{EE} \rightarrow \text{EEF S} \); where EEF is Edit Extensio Found as:

(28) \( \text{EEF} \rightarrow \text{EE}_{\text{found}} \text{E}_{\text{current}} \text{-extended} \text{EE}_{\text{destructed}} \), which means subtract the not rectangular part of the sketch, \( E_{\text{current}} \), in Extended shape from the rectangular part, \( E_{\text{found}} \), and Edit the resulting Extensio\text{destructed}.

References
Figure 2 - 11 are from (Aalto, 1998), with the exception of figure 6 which is from (Fleig, 1997).

USING IMMERSIVE VIRTUAL REALITY SYSTEMS FOR SPATIAL DESIGN IN ARCHITECTURE

AUTHORS
Dirk Donath
Holger Regenbrecht
Bauhaus University Weimar
Germany
donath@archit.uni-weimar.de

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ABSTRACT
In the very young discipline of Virtual Reality Applications only a few reports
are available about using this technology for periods longer than in
experimental setups. This paper describes experiences made during four
years of usage of Virtual Reality (VR) in educational training for architects.
About 100 different people were working with our systems during this period.
Two programs were developed at Bauhaus University with the aim of teaching
students in architecture in three-dimensional sketching. An other program for
free and own interfaces and environments is currently under construction and
will be presented at the international computer fair „CeBit“ in 1999. The first
program called voxDesign is based on the metaphor of voxels. The second
program, planeDesign, uses rectangular planes to describe room-like
situations. All programs force the users to design in a 1:1 scale, which means
that the design and the feedback actions are coupled in an embodied way. A
real walking metaphor is used for navigation. The experiences made by the
students are explained too.
USING IMMERSIVE VIRTUAL REALITY SYSTEMS FOR SPATIAL DESIGN IN ARCHITECTURE

1. Position statement

Virtual Reality in Architecture. This paper does not consider the different kinds of digital architecture, many articles were published in the past and only few results were shown. Most of the discussions try to give new impulses using terms like trans- or avatarchitecture (Novak, 1991, 1996) or Peter Eisenmann with his attempt of a virtual house (Eisenmann, 1997). We want to focus on what is possible with computers in a more qualitative than quantitative meaning.

We want to show that at least two things happen in the area of Computer Aided (Architectural) Design (CAD):

a. there are new methods of interaction with digital architecture and
b. digital and solid architecture will change itself by using these new methods.

Our attempt is to provide first approaches towards a Virtual Reality Aided Design (VRAD).

2. Computers in the architectural design process

19 years ago Hoskins (1979) published a work about simple design techniques using computer technology. The users (architects) were given small bricks as a design tool. The surfaces of the bricks were electronically recognizable by a computer. The computer generated a three-dimensional model according to the position of the bricks. This approach is very different to ways of interaction in todays CAD systems: no knowledge of the program was necessary! On the other hand the possibilities of expression were very limited due to the limitations of the bricks itself and were not limited to the simplest interaction techniques of this system! Based on everyday experiences complex digital models could be build by simply aggregating atomic elements. Virtual Reality technology could serve as such an intuitive, almost unrestricted tool for architects among other designers to express their ideas in a very creative way.

Since a few years this VR related techniques are being used for virtual walkthroughs through digital (CAD-) architectures and are well known in the architectural field (figure 1).
The VR principle of three-dimensional interaction with the digital environment and the situation, to be an autonomous part of this world could lead to the hope, to create new design support techniques\textsuperscript{i}, similar to the researcher about the mentioned digital bricks. Other work in this direction could be found at the HITLab\textsuperscript{ii} in Seattle, at the University of North Carolina, at the University of Virginia and at other institutes\textsuperscript{iii}. Figure 2 shows the elementary parts of a VR system for the three-dimensional design work.

![Figure 2: components of the functionality for VR system for the three-dimensional design work.](image)

Based on this promising approach we have started at the Bauhaus-University Weimar\textsuperscript{iv} several projects during the last years.

The following goals and desires serve as a basis for our research activities: providing intuitive usability through unspecified design tools generating and experiencing the designed world in a 1:1 scale communication with and within the virtual world; this means the architectural design objects and elements are able to be modified and could interact with each other, for example could change their size and the relation or position.

extending the expressibility of solid and virtual architecture, developing new ideas and forms of architecture\textsuperscript{v} close implementation-usage loop experimental usage and enjoyment

3. Requirements for the intuitive usage of VR-techniques in the architectural design process
The technical possibilities of VR are not sufficient for a successful design in such an environment. Some research was undertaken about communication and interaction in virtual environments but mainly without paying attention to a specific discipline or task, especially not for architecture. Furthermore a lot of research was done about improvements of technical parameters, especially investigating a high seperation of the users from the real world (immersion) and about the development of highly realistic presentations (resolutions etc.).
On the other hand questions of the psychology of perception are subject to a lot of research, e.g. in the treatment of phobias (fear of height, spider phobia). These developments are of interest because the presence is their fundamental background. Otherwise the patient could not be treated. In our case of architectural design and evaluation the so called "sense of being there" is a substantial psychological state for the successful usage of such a VR system. Some basic contributions to this field were also made at our university (Regenbrecht & Schubert, 1997).

Finally a VRAD system should consider the theory and practice of architectural design as it is seen today. The process of design is very complex and difficult to formalize (Schmitt, 1993, 1996). With our approach we follow theories which focus on the act of design instead of the result. A very promising theory of the design process could be the one provided by Christopher Alexander (Alexander 1977), it can be lined out as follows:

"...to design, it is essential . . .
...to work on the site, where the project is to be built,
...to work with the people, that are actually going to use the place when it is finished,
...to begin as something very loose and amorphous,
...to close your eyes, to have a undisturbed stream of ideas and thinking,
...to do this in a loose and relaxed way,
...to keep this total area in your mind,
...to make the essential points and lines which are needed to fix the design result,
...do not try to design on paper ..."

A first step towards a VR system which follows these statements was to implement some applications with a basic and simple functionality. Our approach is very humble but it serves as a subject for discussion, evaluation, and critique and does not mean a universal solution.

4. Three VR-Applications used and usability reported
At Bauhaus University Weimar, a strong relation with Virtual Reality Architectural Design (VRAD) systems exists. Since 1994, when the multidisciplinary project atelier virtual was founded, three VRAD systems have been developed, namely voxDesign, planeDesign and VRAM. The voxDesign software environment specifically focuses at sketch oriented creation of spaces with voxels, whereas planeDesign is space oriented making use of planes. VRAM is using both concepts, based on a new software implementation, where all interfaces and the design world itself are able to be described on the same way: with easy modelling and editing functions inside or outside this VR system.

All systems make use of a Virtual Research VR4 Head-Mounted-Display, a stylus, a magnetic tracking device and the at the university developed platform construction. To allow the user to interact with the virtual environment without technical restrictions (like the many cables) and to keep the basic needs of an unconstrained, natural design process within the virtual environment the wooden platform construction enables a movement in a 4x4x2.5 meter in an almost unconstrained working and walking space. All applications described
here are working in combination with this construction. (Regenbrecht & Donath 1997)

Figure 3: a concept to use gestures\textsuperscript{vi} in a virtual design environment (J. Lehmann, 1995; www.uni-weimar.de/iar).

4.1 voxDesign, 1995
The first application developed is called voxDesign. It uses voxels, cubes with 2.5 centimeters edge length, as the atomic medium of expression. Voxels can be positioned in space just by sketching them using a pen-like device (Polhemus Stylus) and a head-mounted display as an output device. For the users of this simple software there was nothing to learn except pushing a button and getting a three-dimensional menu for activating some additional functions.

Figure 4: one of the first example of a design result with voxDesign: A. Brechtel, D.Donath, Bauhaus University Weimar, 1995.

4.2 planeDesign, 1997
The second application (planeDesign) is as simple as voxDesign and uses rectangular planes to design spatial situations. In addition to that some object-based interaction techniques were tested with planeDesign always taking into account that the software should be usable without any training. Figures 5 to 8 are showing views out of the virtual environment.
"To design is not to know what you are doing, but to feel, you are right."  

The starting point to develop this kind of space definition is based on one of the main meanings of architecture: to define artificial space in form of setting up "borders" between our natural environment. PlaneDesign is a tool for the conceptual phase in the design process, to get directly from your ideas (and mind) a more clear picture about your raw design solution in a scale of 1:1. While voxDesign respects one of the main techniques in the design process - sketching - , PlaneDesign reflects the elementary intention of architecture: space. We have no scale, no measurement abilities, no exact positioning tools, only an intuitive way to create planes to define different spaces. Using a real - digital - stylus the architect describes flat walls, ceilings, floorings or what ever in a flexible position. The results showed in figures 5-8 are maybe simple and boring: but please consider, that these are pictures of a directly interpretation of the mind and ideas. These results transform into more accurate CAD or CAAD systems is easily possible. It is also possible to embed CAD models as a starting point or design context in your VR environment. The exchange file format is VRML or DXF.

4.3 VRAM, 1999

With VRAM we are able to overcome the twodimensional interface barrier afforded by desktop screen and mouse to interact with typically threedimensional virtual reality models. The program VRAM is designed for viewing, browsing, editing, and modelling three dimensional models based on the Virtual Reality Modelling Language (VRML). The focus is set on experiencing and interacting with large scale architectural models. VRAM serves as a testbed for threedimensional user interface (3DUI) techniques to allow better navigation, orientation, and modelling within virtual environments. VRAM is both a research and education project at Bauhaus University Weimar, and an immersive virtual reality software environment running on
different platforms (Windows and UNIX) using certain I/O-devices (magnetic tracking, head-mounted display, stereo projection screen). Phase I of IV implements an immersive VRML browser, basic editing functionality, and some selected modelling approaches. Different interfaces can be chosen and generated by the user of the system. The following phases of this project will upgrade the system to a flexible and comprehensive virtual reality aided design (VRAD) system.

Figure 9: Examples of using the VRAM software: real design environment, Bauhaus University Weimar, 1999.

Figure 10: Examples of using the VRAM software: user specific shape of the stylus tool, VRAM, Bauhaus University Weimar, 1999.
In figures 9 to 12 you are able to see the whole environment: the user with HMD and stylus, situated on the platform and working in front of the projection wall, where you are able to see the current view of the designer. Each user can create their own interfaces in form of command related 3D icons. In a initial text file has to be set up the relation to the commands of VRAM. We will present this software and environment at first at the International Computer Fair CeBit in Hannover in March 1999.

5. Digital Space: How should be the architecture for the virtual world?
Virtual environments differ significantly from the real world. While this is true, there are many things for the real world that can and should be applied to virtual space. Because virtual environments are at least and in a sense, spatial interfaces, conscious and unconscious design issues like symbolic meaning and metaphors perceptual, and cognitive factors must be considered.
In fact, a human is a life on the earth, with a fixed behaviour. A human is a member of a society with a certain form of communication behaviour and certain regulations and relations there. A human is a psychological phenomena with traditions, subjective and objective kinds of thinking which leads to specific activities. Therefore, independent if it is a real or virtual environment, we have to consider the well known roles, regulations and consequences of the environment to be a human.
It is not successful to follow all of the possibilities and freedoms of digital arrangements! For this moment it seems to be interesting, impressive and „possible“ to play with the definitions of space, size, order and architectural functions, ... to play with architecture. But the results will come back soon: disagreement, disorientation, unpleasant, boring, bothering, leading to illnesses and sicknesses.
In the last three years we are looking for rules and new or existing knowledge about the form and laws in a threedimensional digital space.
We believe, that
We need a space, following our human background and experiences.
We need a space, following our social regulations.
We need a well known space with well known metaphors and symbols. The author has worked in a research project at the HITLab, where we integrated a design theory of Alexander (Alexander 1979) to develop a method based on case use pattern language, that exposed usability issues early in the process and allowed us to better define requirements for the being and the content of a digital world. (Tanney et al. 1998)

This theory, the Pattern languages have been recognised in many disciplines as a way to address the whole and the parts, the big picture and various levels of detail. Christopher Alexander's, A Pattern Language, is an architectural design method that sequentially walks planners and designers through various patterns from a global scale to a local and more intimate scale.

In combination, these patterns can be used to realise human environment relationships that translate into design requirements and offer greater meaning and significance for the new kind of architecture and it's sense.

To consider affordances of virtual space and the user's expectation from real world constructs, architectural could help to define a new meaning for space, form, and order. Patterns regarding proportion in the virtual world are able to describe similar relationships or add a layer of interface issues which alter the real world reference to scale.

Patterns like transition spaces, entrances, public and private space are necessary and helpful to make the first step for defining a new and familiar world too: through careful analysis of the scientists from different fields of experts it could be possible to lead Alexander’s „human needs“ in the digital space. The interdisciplinary nature of the design of virtual environments makes it necessary to consider issues from multiple perspectives.

5.1 Student design project: architectural pattern for a digital environment
Since 1998 students are working on a reflection of the Alexander’s pattern for a digital world. You are able to see all results and discussions at the homepage of this project under the instruction of the authors. The results are impressive and creative for a new stage of defining the virtual world: in fact, it is necessary to respect the role and meaning of architecture in this world too! Some examples are showed in figure 13. (see http://www.uni-weimar.de/iar, link: [digital space])

6. Summary
It was not the main goal of these projects to serve as a testbed for VR usability in general. The main focus was set on some tools and ideas for the very early phases of the architectural design process. But nevertheless some statements about usability can be made, of course without any serious empirical background. The results were gained by frequently applied questionnaires asking for the general convenience with the system and by verbal reports given by the users of the applications to the staff. Each student used our VR systems a couple of hours in practice to realise the design task, each session lasting an average of about one hour (between 30 minutes and 3 hours).

Some results of a more general interest are presented here in brief:
- using the system continuously longer than 1 hour led to simulator sickness in about one third of the students.
- the pen metaphor (Stylus) exhibited very good usability for the given task; the students associated it with sketching
- sometimes there were problems with the stability of the tracking system, this very decreased task performance
- it is not necessary to provide as much colours as possible, 16 colours (in voxDesign) are sufficient for the design task
- during long sessions the students tended to lay down on the floor during the design process
- the most spectacular effect was to "experience" a virtual structure by just going around it
- a stereoscopic head-mounted display is not that necessary, other depth cues are much more important
- the selectable value for the field of view is very dependent on the individual (between 30 and 100 degrees)
- the estimated duration time by the student was shorter every time than the real time
- most of the students were immersed (or at least involved) in the virtual space during their design sessions
- for longer periods of usage the head-mounted display is not very comfortable

7. Discussion
The main advantage is a report based on real task driven usage of a system. Our current projects will combine educational training in a wider range of tasks with usability testing based on evaluation methods with statistically significant results. We started last two years with such statistical verified questionnaires about fields of research like Immersion, Field of View, Sense of presence. The work is done especially by Regenbrecht for his current doctoral qualification.

The whole discussion is in progress. We are able to try, to test and to evaluate our opinion about the sense of and the being in the virtual world. Not more. That's why we should work together and hear to the voice of the new generation.

8. References


\( ^i \) Besides wellknown and used techniques like early sketch work, a working model and textural / pictural description

\( ^ii \) especially between 1994-1996 were developed many projects like GreenSpace I/II and Blocksmith at the Human Interface Technology Lab in Seattle, http://www.hitl.washington.edu/projects/


\( ^iv \) atelier virtual: interdiscipline research team with architects, designers, specialists of information sciences, psychologists (see www.uni-weimar.de/architektur/InfAR/forschung/vradmin.html) in the field of VR at the Bauhaus University Weimar

\( ^v \) see the social discussions about the Virtual Architecture, a kind of architecture only in digital form (Virilio 1994)

\( ^vi \) research about gesture recognition and their using in VR-systems is based on different motivations too: see http://www.peipa.essex.ac.uk/gesture/tools/ or http://www.percep.demon.co.uk/pfo3rd.htm

\( ^vii \) a more funny interpretation, explored in a discussion with G. Schmitt, ETH Zurich at the IKM conference 1997 in Weimar

\( ^viii \) http://www.uni-weimar.de/iar
VIRTUAL DESIGN FOR INNOVATIVE TIMBER STRUCTURES

AUTHORS
Rodrigo García Alvarado
Ricardo Hempel Holzapfel
Juan Carlos Parra
Universidad del Bio-Bio
Avda. Collao 1202
Concepción
Chile

ABSTRACT
The major timber structures have great efficiency and beauty, but not many use in buildings due difficulties to represent and resolve theirs geometrical complexity, regulated by several constructive rules. The spatial richness and attractive of these structures can be a contribution in architecture, and encourage the use of wood.

For aid the design and impels innovative solutions we are developing a computer system to program the geometrical regulations and allow a tridimensional visualization of different models with virtual-reality devices.

First we are studying the architectural morphology and design process of structures more typically used; beams, trusses, frames and arcs. Establishing theirs proportions, distribution, shapes alternatives and the computational algorithm.

In other hand we are evaluating the 3D-visualization in the innovation of designs. Some students of architecture developed in a virtual-system small projects based on other projects designed with traditional media. The models were compare by a panel of professors, considering overall quality and creativity.

The results of that experience shows advantages in geometrical innovation, specially in organic shapes user-centered instead of orthogonal compositions. But also some constructive fails, which is necessary to support with related procedures.
VIRTUAL DESIGN FOR INNOVATIVE TIMBER STRUCTURES

1. Introduction
Wood has a long tradition in construction, but few use in major structures due to constrains for big pieces. However, new products such as glue-lam wood or composite boards, allow better structural behavior with minor sections, opening new possibilities of design, as demonstrated on recent architectural works based on strong personal talents [Hubner;1993, Makovecz;1992] which use, like other linear structures, a big amount of elements in different directions. Besides, the architectural potential of wood is related to their natural characteristics; organic texture, warm colours, stable temperature, low sounds, etc., closer to human sensitivity, establishing a semantic base for organic shapes and spatial richness [Harris,1998]. These two properties encourage the architectural use of complex geometries to take advantage of efficiency and natural appearence of timber structures. But designing with orthogonal drawings difficulties the visualization and organization of intricate shapes [Zevi, 1951]. Then, we proposed a computer system to program the geometrical regulations of timber structures and to get a three-dimensional visualization using virtual-reality devices, looking for implementing a design tool to generate proper and innovative architectural models, that impel the use of wood in major constructions.

2. Morphology of Timber Structures
The first stage was to study the architectural morphology of timber structures to define the regulations and possibilities of innovation. The morphology depends basically on the general volume of building. The most common are longitudinal volumes constituted by planar systems in repetitive sections [Natterer et al, 1991]. Horizontal or vertical volumes can be made with laminar, spatial or frame systems, but they are few and specific. The planar systems and the amount of elements are arranged with proportional relationships between width, height and length of volume, based on functional requirements and constructive effectivity. The planar systems are usually composed by four types of elements; beams, trusses, frames or arcs. Each one increased in complexity of production and growth in structural capacity. So each type is related with increasing the dimension of volume, with a stable amount of elements. Because the function of buildings requires some width or height, this requirement can establish the type of elements to be used and all the general dimensions. The size of the pieces are proportionally regulated from the main dimensions by constructive and structural efficiency (including also some constraints for transportation). The major variations are found in the shape of pieces, but frequently between range of angles or proportions defined by functional issues such as useful spaces, rain water run-off or constructive solutions for joints and cladding. Establishing several formal alternatives with progressive sizes. Also there are important variations in the distribution of pieces, based in linear
or radial organizations, although proportionally regulated by constructive performance and functionality. Some of these variations in types, shapes and distribution involve strong differences in the architectural volume, defining spatial qualities, that must be related to the character of the activity. Then, based on the function and size of the building, an algorithm of alternative shapes and formal proportions of timber structures can be defined, to establish several models including unusual possibilities.

3. Implementation of Virtual System
The design system was mounted in software VRT-5 (Virtual Reality Toolkit 5.0 of Superscape Co.) because it offers a language programming called SCL (Superscape Control Language, similar to “C”) and an interactive 3D-visualization engine that control several virtual devices. That platform also allows to use a free browser (Visualizer-Viscape) and a trial-version of the modeling toolkit (3D-WebMaster). Up to the date, a functional prototype of the immersive design system has been developed [García et al, 1998], that introduce the user into an open landscape with a handy control to define dimensions and to choose formal alternatives. Then, based in a library of shapes and the geometrical relations programmed, the system generates three-dimensional models of the structures where the user can walking-in, evaluating the spatial result and creating other solutions in an interactive design environment. It also includes a human body to scale the models.

Figure 1 : Design Environment (in Superscape VRT 5.0) and Immersive Device (Forte VFX-1).

According to our experience the models must have less than 2.000 facets to allow a fluid navigation (this means a visualization closer to 15 frames per second) in an standard PC-Pentium. This situation restricts details like joints, minor pieces, divisions and furnishings (although aid to a quick creation of models). Besides, it simplifies the appearance, using one light source and flat colours (not real textures), and controls the complexity of programming and the amount of simultaneous models. Usually the 3D-software optimize the visualization by sorting the geometry, but in this case the models are created in the moment by the user and is not possible to predict the geometries. Then, there are rendering problems in radial structures and non-orthogonal distributions. For immersive visualization we used a low-cost helmet and 3D-pointer (VFX-1 and Cyberpuck from Forte), which includes two little LCD-screens, rotation tracker and headphones. The navigation was difficult by the handy control of
three-dimensional movements, lower visual quality and the occlusion of the helmet which produces sickness and tireness.

4. Evaluation of Virtual Designs
To evaluate the contribution of interactive 3D-visualization to the architectural creation of major timber structures we made three designs with fourth-year students of architecture. Each project was based in a real building designed with conventional media in timber structure, with a main space of around 200 square metres, devoted to different uses; a High-school Gymnasium; a social room for religious activities and an Industrial Pavillion for wood production. The students were encouraged to visit the buildings, to know the activities and to study the morphology of timber structures prepared to the system.

They re-designed the projects almost exclusively with the 3D software, modelling several alternatives and checking them with the immersive helmet. Although at the beginning they made some sketches by hand, during the work they take major decisions and made changes directly in the computers. By the geometrical constraints they were impelled to define a rough design without constructive details, choosing in the end one alternative for the three projects, as an “experimental group” for the evaluation. Also, they modeled in the software the original projects with a similar level of detail, as the “control group”.

Figure 2: Gymnasium; original project (left) and virtual design (right).

Figure 3: Social Room; original project (left) and virtual design (right).
After that, the six models arranged in pairs according to their function, were evaluated by a panel of ten critics of architecture (professors of architectural design of different levels and institutions). Each sessions considered the presentation of printed views, guided tours of the models in the computer screen and/or visualization with the immersive helmet. Finally, they respond a similar questionnaire about the designs.

5. Results and Discussion

For evaluating architectural quality is a polemic issue, we based the questionnaire in a traditional reference, the Vitruvian's categories: utilitas, firmitas and vetustas (functionality, stability and esthetic). We consider two complementary questions about each category (ranged from 1: bad to 10: good), plus one of overall coherence and another specific one about innovation (usually a positive value in architecture, but not directly related to quality).

Table 1: Results of Evaluation by Critics of Architecture.

<table>
<thead>
<tr>
<th></th>
<th>GYMNASIUM</th>
<th>SOCIAL ROOM</th>
<th>INDUSTRIAL PAVILION</th>
<th>SUMMARY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original</td>
<td>Virtual</td>
<td>Original</td>
<td>Virtual</td>
</tr>
<tr>
<td>GENERAL</td>
<td>0.98</td>
<td>4.60</td>
<td>6.20</td>
<td>0.60</td>
</tr>
<tr>
<td>FUNCTIONALITY</td>
<td>7.00</td>
<td>4.80</td>
<td>7.00</td>
<td>0.60</td>
</tr>
<tr>
<td>Capacity</td>
<td>7.60</td>
<td>6.20</td>
<td>7.10</td>
<td>0.50</td>
</tr>
<tr>
<td>Structure</td>
<td>8.40</td>
<td>5.00</td>
<td>8.30</td>
<td>2.20</td>
</tr>
<tr>
<td>Stability</td>
<td>0.09</td>
<td>4.00</td>
<td>0.10</td>
<td>7.20</td>
</tr>
<tr>
<td>Construction</td>
<td>5.60</td>
<td>7.00</td>
<td>5.70</td>
<td>4.70</td>
</tr>
<tr>
<td>AESTHETIC</td>
<td>0.50</td>
<td>6.10</td>
<td>5.70</td>
<td>2.70</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>6.60</td>
<td>6.70</td>
<td>4.00</td>
<td>7.30</td>
</tr>
<tr>
<td>Innovation</td>
<td>5.20</td>
<td>5.00</td>
<td>4.20</td>
<td>6.00</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>7.40</td>
<td>6.00</td>
<td>6.40</td>
<td>2.80</td>
</tr>
<tr>
<td>Difference</td>
<td>-1.40</td>
<td>1.40</td>
<td>0.40</td>
<td>-0.40</td>
</tr>
</tbody>
</table>

The final average of the questionnaires shows peculiar differences within the three projects; in the social room the scheme created with virtual system qualify 20% better than the original one made with traditional media, but in the gymnasium the results are inverted and in the industrial pavilion are almost matched. This reveals the big amount of additional variables in architectural design (theme, proposal, designer’s capacity, etc.), which disturbs the
reliability of results. Besides the few cases studied and lack of statistical base obby to consider that experience only as an example. The total summary of evaluation lead to a close matching between virtual and conventional techniques. Then, it is possible to say that to generate the design with virtual systems do not produce major differences in the overall quality. But it is also important to notice the differences by subjects, the traditional projects were better evaluated in functional and constructive issues, and the design created by virtual systems in esthetic and especially in innovation (66% better). This result support the initial hypothesis about a positive contribution of virtual design in the creativity, but also warned about pitfalls in functionality and constructive solutions with that media.

It is interesting to note similarities in morphology of designs created with virtual systems. In each case the shape of spaces were “rounded”, with a central organization in the social room (although with straight pieces), with a linear increasing-decreasing organization with diagonals in the gymnasium, and with curved pieces in a complex distribution in the industrial pavillion. The three projects apply more complex geometries, with three-dimensional rotations and a perimeter in a more “constant distance to user” than orthogonal buildings. This reveals the predominance of user point-of-view to define the design, instead of 2D regularities used in the traditional media, impelling innovation with organic and centralized spaces, instead of orthogonal and aggregated organizations.

![Figure 5: Sketchs of Spatial differences from conventional (left) and virtual design (right).](image)

Besides, the shapes used in all virtual projects difficult the perception of distance and dimensions. However that characteristic is related to complex geometries and encouraged by simplification of appearance in the virtual media. The designers don’t take attention to use grids, regular rhythms or orthogonality to give orientation and dimensions. The projects focused in the visual impact instead of right forms.

These two characteristics of the schemes; organic centrality and visual predominance can be influenced by the ecological issues and broadcast media increasing in our culture. Two strong (and in part contradictory) trends of current society, showed in the sentence used by Peter Einsenman to describe the zeitgeist (the spirit of the time); “dissociation between body and mind-eyes” [Zaera Polo, 1997]. Although that kind of link could be casual, is important to relate the formal innovation in architecture to concepts and cultural view to focus creativity like an evolution, instead of alleatory formal play.

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VIRTUAL REALITY IN EARLY DESIGN: THE DESIGN STUDIO EXPERIENCES

AUTHORS
Henri Achten
Arthur Turksma
DesignSystems Group
Faculty of Architecture, Building and Planning
Eindhoven University of Technology
Den Dolech 2
5600 MB EINDHOVEN
The Netherlands
H.H.Achten@tue.nl
A.A.E.Turksma@tue.nl

ABSTRACT
The Design Systems group of the Eindhoven University of Technology started a new kind of design studio teaching. With the use of high-end equipment, students use Virtual Reality from the very start of the design process. Virtual Reality technology up to now was primarily used for giving presentations. We use the same technology in the design process itself by means of reducing the time span in which one gets results in Virtual Reality.

The method is based on a very brief cycle of modelling in AutoCAD, assigning materials in 3DStudio Viz, and then making a walkthrough in Virtual Reality in a standard landscape. Due to this cycle, which takes about 15 second, the student gets immediate feedback on design decisions which facilitates evaluation of the design in three dimensions much faster than usual.

Usually the learning curve of this kind of software is quite steep, but with the use of templates the number of required steps to achieve results is reduced significantly. In this way, the potential of Virtual Reality is not only explored in research projects, but also in education.

This paper discusses the general set-up of the design studio and shows how, via short workshops, students acquire knowledge of the cycle in a short time. The paper focuses on the added value of using Virtual Reality technology in this manner: improved spatial reasoning, translation from two-dimensional to three-dimensional representations, and VR feedback on design decisions. It discusses the needs for new design representations in this design
environment, and shows how fast feedback in Virtual Reality can improve the spatial design at an early stage of the design process.
Representing floor plans for interactive evolutionary design
VIRTUAL REALITY IN EARLY DESIGN: THE DESIGN STUDIO EXPERIENCES

Goals of the design studio
The Design Studio started in its current configuration in 1998. It was founded with the following purposes in mind:

1. To facilitate the research programme VR-DIS of the Design Systems group. VR-DIS stands for Virtual Reality - Design Information System (Achten et al. 1998). The studio was to provide the hard- and software to develop the research projects on, and to provide a testing environment for system prototypes.
2. To facilitate and innovate design education by incorporating this technology in design studio teaching.
3. To mutually influence research and teaching by integrating the products of research in the design studio, and to explore in the design studio the boundaries of new technology.

The primary goal of introducing VR-technology in the design studio is not to use it as a presentation tool at the end of the design process, but to use it from the very start of the design process. Currently, typical design studio work seldom uses the computer in the formative stages of design. It is only slowly making its entrance in the sketch phase in a mixed use with drawings and scale-models.

By providing the hardware, software and the working methods that increase the use of the computer, we hope to explore and push the boundaries of what is possible with the computer in design. The student work and research work in this respect can inform each other and provide feedback.

The design studio consists of six Intergraph machines that run on WindowsNT. The machines are dual-Pentium II 400 MHz machines with 256 MB RAM. They are equipped with Intergraph RealiZM GT videocards with 16 MB frame buffer memory, 16 MB texture mapping memory, and geometry acceleration, specifically designed for real-time graphics. The systems are completed with 21” monitors. For projection purposes, there is a projector and a screen. All machines are on a network. Students have individual accounts and space on the network hard-disc. They can work together by sharing directories. The basic software is AutoCAD r14 for modelling, 3DStudio Viz2 for modelling and visualisation, WorldUP for Virtual Reality, Photoshop for graphics, and Internet and Powerpoint for presentation (see Figure 1).
Normal design versus the VR-cycle

In the recent years that CAD has been introduced in the design studio, its typical use is that of a modelling tool, used separately from sketching and scale-modelling, and without much interaction between those activities. VR as a technology has been explored to some extent in various approaches (for example Bridges et al. (1997), Bourdakis (1997), Caneparo (1997), Shih (1997), Wall (1997), Bradford et al. (1997), Terzidis (1998), Wong et al. (1998), Dobson (1998), Klercker (1998)), but is not yet widespread. Given the focus of the Design Systems group on Virtual Reality, we have chosen to introduce this technology as our specific approach to the design studio.

In the spectrum of abilities required in architectural design, three-dimensional reasoning is a key issue. The organisation of space in a design often informs (and is informed by) the materialisation, structural design, HVAC installations, and the implementation of function.

In the majority of CAD software, making and using three-dimensional representations requires many additional actions from the user part. The link between two-dimensional and three-dimensional representations is tenacious and not adequately supported. Also, the interface of the software is inherently two-dimensional, often based on the common desktop-metaphor. These factors inhibit a fluent transition from working in two-dimensional representations such as plan and section to a three-dimensional representation.

Virtual Reality technology has a few interrelated characteristics that improve on the factors stated above:

- Immersion. The perspective projection of the design on a monitor or head-mounted display gives an accurate image of the design as perceived by an observer inside the design.
- Real-time rendering. Fast rendering enables a steady flow of images of 15-25 frames per second, which gives the idea of continuity.
- Position and orientation feedback. The linking of rendering images to position and orientation and in particular to match these images with changes in real-time greatly enhances the effect of immersion.
• Interactive manipulation of the digital environment. Objects and elements in a VR model can be changed and the effects are shown in real-time.

In short, Virtual Reality provides an immersive environment which permits real-time walkthroughs in a design. In Eindhoven University of Technology there is a long-time experience with the use of this technology, in particular through the work of Calibre Institute. Up to now, it required powerful computing systems and a lot of fine-tuning of the model to optimise results. This inhibited regular use of VR in the design studio. With the installation of the Design Studio, however, machines and software have become available that allow quick and (almost) ubiquitous use of VR.

The VR cycle: AutoCAD/3DStudio/WorldUp

The software that is used in the Design Studio (AutoCADr14, 3DStudio Viz2, and WorldUP) normally is seen as quite separate from each other. They all read some standard file-format (DWG, DXF, or 3DS) but they are conceived as single programs.

The so-called VR-cycle in the Design Studio enables the integration of the software that will allow quick switching between various representations. There are two versions of the cycle:

1. AutoCAD/3DStudio/WorldUP: The design in any stage of the design process is made in AutoCAD. The model is loaded in 3DStudio Viz (which runs parallel to AutoCAD) by means of the DWG link manager. Materials are assigned to elements of the model, after which the model is loaded in the WorldUP Player. The model is inserted in a standard landscape and the designer can walk through it in real-time. Normally, creating a model for a VR walkthrough is a complicated process, but the use of template technology for transferring models and creating the standard set-up greatly facilitates this process. Evaluation of the model in VR can lead to changes in the AutoCAD model, which are immediately sent to 3DStudio because of the DWG link manager. The first time the cycle is set up, it takes about five minutes. The second time, many actions can be left out, and a change in the AutoCAD model can be seen in VR within 15 seconds time.

2. AutoCAD/WorldUP: In this cycle, the step 3DStudio is left out, and WorldUP directly reads the 3DS file exported by AutoCAD. This is even faster than the previous cycle, but the model will lack material renderings that use texture maps, and display colours as they are defined in the layers of AutoCAD. This method is well suited for studies of mass and proportions.

In principle there is also the cycle 3DStudio/WorldUP, but this is at the moment not used since AutoCAD is the predominant modelling tool.

Although students need to have knowledge of modelling in AutoCAD and limited knowledge of 3DStudio Viz, the VR addition does not require additional knowledge. AutoCAD and 3DStudio are part of the regular curriculum of the IT course in the Department of Architecture. The information about the VR-cycle is available on the network for the students. To make the students comfortable with this particular use of the computer, however, we have set up brief workshops that introduce the matter in three hours. In this way, it is also
possible to discuss some additional architectural and computational issues (Achten 1996) of VR in design.

The computational issues concern efficient modelling to increase machine performance, principles of VR, and the use of network facilities. The architectural issues concern incorporation of VR in the design process, and making and evaluating models. Some of these will return in the discussion section of the paper.

Examples of student work
The examples here from student work cover three different uses of VR in the Design Studio:

1. **VR in the early design stage.** This project by Frank Janssen is a running graduation project. From the very start, the VR-cycle has been used to explore and check the architectural consequences of the design. The design task concerns a new design for the station area of Heerlen which needs to locate a complex programme of train station, secondary school, offices, bus station, stores, cinemas, and small police station. VR has served in particular to develop and test the complex spatial relationships between the various parts of the programme (Figures 2, Figure 3).

2. **VR as a presentation medium.** This project by Max Bruner is a graduation project that was completed in 1998. It concerned an urban infill-project of housing in Eindhoven. VR technology and CAD have been used during the whole design process to develop new housing types that are spatially more woven into the local fabric and each other. VR has served in particular to convey the general design, and the individual houses as they are grouped in the conglomerate of the complex. For the final presentation (Figure 4, Figure 5), the VR-model was enhanced by using radiosity rendering as textures for the model, providing realistic lighting information. In this manner, the model could be used twice in different ways.

3. **VR as a conceptual prototype.** This project by Dirk-Jan Bax was a fourth-year project made from the building construction point of view. It aimed to show how a VR model can present the construction order of a building, show placement tolerances, and provide data on elements, suppliers, and time schedule. Based on the design of the student the prototype was programmed in a few hours by Joran Jessurun of the Design Systems group. This project showed how the concept of VR can be expanded to incorporate disciplines that are not yet involved very much in this area (Figure 6, Figure 7).
New and running student projects concern the implementation of design knowledge of structural engineers in the early design phase, the use of genetic algorithms in a VR environment as a form-generating tool, the theme of the "skin" as a design concept, the integration of VR in the design process, and the use of VR to study large scale urban environments.

**Discussion**

The template technology provides synergy between the software programs that up to now are used separately. Students are able to switch fast between the
general modelling tool of AutoCAD to a VR environment to check the design changes in three dimensions.

Students are able to break some mental blocks that traditional two-dimensional representations have such as: stacking and repetition for high-rise, rigid geometric organisations for plans, and limited vertical development of the design.

The computer still evokes a strong focus on the technological aspects, and distracts from architectural issues in the design process. This requires constant attention in the tutoring to teach the student a critical attitude towards the generated image.

Traditionally educated architects find it hard to “read” the VR-models and require two-dimensional representations for judging the quality of the design. In particular in the graduation projects there is a strong call for traditional representations.

Complex and large models noticeably slow down the frames/second capacity of the machines. In our experience, the designing student can handle 5 frames/second and still interpret the consequences of design changes in the VR-model fairly well, but for new observers this frame-rate is obtrusive and distracts from the model.

VR models require a richer visual language to convey the same information as a plan. In urban design for example, a plan can have some geometric shapes indicating building masses, and lines for infrastructure, and those can be quite adequate for judging the urban plan. The same urban plan in VR however, lacks a sense of scale as the buildings typically are extruded from the urban plan. Here, other representations are required to add this information.

We found that both in the presentation phase, and the sketch phase, the strengths of VR lie in conveying the spatial consequences of design decisions, and tackling complex spatial programmes and forms. In this sense, VR can facilitate breaking through mental blocks that “older” representations inherently cause, and thus create new forms of architecture.

VR is not the sole direction to take for future developments of CAD in architectural design, but it is very good in conveying spatial solutions and to study design in the early phase using the VR-cycle. Future work will, among others, consider co-operative design as a number of re-use projects are initiated in which students of various disciplines will participate. Also, design prototypes from running research will be incorporated in the Design Studio (Coomans 1999, Vries et al. 1998, Leeuwen et al 1998).

References
WHEN REALITY FILLS FANTASY

AUTHORS
Rob van Helvoort
Hogeschool West-Vlaanderen
Departement Simon Stevin
Rijselstraat 1
8200 Sint-Michiels – Brugge
Belgium
Rob van Helvoort

WHEN REALITY FILLS FANTASY

Reality
The moment one takes a look at the opportunities for work in the professional world of architecture one cannot help but notice one important point: It is no longer the skilled architect who is wanted most; it is the professional draughtsman industry is looking for.
I happen to be privileged to teach at an institute of higher education where young individuals are trained to become this essential part of the design office. At our school, next to almost every other skill you can use in the office, extensive instruction in and by Computer Aided Design (CAD) is a major part of the training. The software package for CAD we use is AutoCAD, a design tool used by a major part of industry worldwide. We teach both 2D- and 3D-drawing, wireframe and solid modeling, as well as some basic programming skills.
After having had students in practical training for some years now, both in Belgium and in other European countries, we have discovered it does not really matter which CAD package is used in the design office they work in. Having an AutoCAD background means that most of the time it is only a matter of hours for one to be able to work with almost every other CAD program. Even better; within weeks quite a number of our students actually became responsible for the CAD-department in the office.

Education
Where does this knowledge take us as an institution of education? For the moment we think we can turn out persons skilled up to the level the professional world asks for. We can confirm this pretentious statement by the fact that up to 80% of our students have jobs even before they graduate. However, in order to be an interesting place for a student to come to, for us, next to a constant update on our CAD courses, it is essential always to be one step ahead of what the professional world is looking for.
At present the topic really wanted by the professional design office is a three dimensional (3D) presentation of a project. But that only is the beginning.
Today, a 3D presentation no longer only is a drawing with hidden lines, but it is a design with 'real life' materials applied to the 3D structure. There is ambient or spotlight in the right place and a professional render to finish. The next step is a 'walk-through' this 3D presentation. At the moment the price of hardware needed for such a walk-through is affordable, even for a smaller organization, thus enabling almost every design office to make animations. The only thing which lacks is skilled personnel. As the number of staff needed well exceeds the amount of students leaving school, the professional world is faced with a huge problem.
ICT
In order to solve part of the problem we have now started to introduce ICT (Information and Communication Technology) as a new technology within the traditional world of education. In this way we hope to increase the level of education by computer in the field of architecture, both for CAD as well as other, most of the time graphical, computer-programs. Next to a rise in quality, ICT also enables us to make our courses available to almost anybody who wants to use them, using the Intranet (local network) of the participating institutes of education as well as the Internet.

Starting point
Before setting up a research project for the use of a new technology in the world of education, we searched, worldwide, for Information and/or Communication software already available; we didn't want to reinvent the wheel. During this virtual trip around the world, we found the USA to be some steps ahead of us, using the computer in a wide range of open- and long distance learning. However, most applications we found were nearly always 'text-oriented' only.

A little closer to home, in Belgium and the Netherlands, ICT is a very popular topic to talk about but, next to some international e-mail projects and Open Universiteit Heerlen, Information and Communication Technology most of the time is limited to a premature status in the minds of some fanatics. This knowledge, together with specific graphical demands of CAD and the possibility of an extensive use of computer technology available, made us develop a new concept we named MECANO (Modules voor Educatie in Computertechnieken voor Architectuur met behulp van Nieuwe Onderwijs technologie -- Modules for Education in Computertechniques for Architecture using New educational technology).

Inspiration
But where did the inspiration come from? There is an abundance of motivation.

The current system of education at this level stands for large numbers of students one has to deal with at a time. There also is a tendency to a reduction of hours the students actually have to be present at site. As a result, students only have limited access to computer infrastructure.

As there are no specific exams students have to take before they can enter, each student has a different level of education starting at one of our schools. Besides, every student has his or her own speed of learning. It is obvious these conditions make it almost impossible for us to help them with individual problems, check progression...etc.

At the same time, Internet and Intranet are available at our schools, theoretically enabling students to take a course where and whenever they want to. The Net also should enable staff to keep their courses up-to-date in an easy way; only think of the annual upgrade of almost any software package and start to realize how much you are in need of a lenient method to change your course.

The earlier AVOCAAD (Added Value of Computer Aided Architectural Design) research project resulted in educational material which generates a creative use of the computer in architectural education. Thus creating the need to
develop a user-friendly interface to encourage the use of these new components.

**Result**

As result the MECANO project will create a database, grounded on the most recent web-technology which enables to create web-pages using a dynamic method. In this way, the student interface no longer uses statically web-pages, identical for everyone consulting, but generates a new page for every user, dependent on their statistics in the database. Using this procedure, there is a personal approach which deals with the different level of education students have as well as the different speed of learning.

Staff will get an interface which enables to build, maintain or update their courses on the Net in the easiest possible way without any specific knowledge of programming languages required. Next to this, staff will also be able to react to any electronical question or remark any student posed. Exercises can be graded automatically; the progress students make is stored in the database and can be consulted at any time.

To test student- and staff interface, a limited number of modules will be developed; two CAD tutorials (AutoCAD and STAR Archi) and a spreadsheet (Excel) for architectural use. Each of these modules will consist of a set of dynamic web-pages which:

- offer the possibility to acquire basic knowledge and skills to the level of a trainee in the design office;
- offer the answer to Frequently Asked Questions (FAQ);
- offer regular exercises according to the knowledge and skills acquired;
- offer integrated exercises which round up specific subjects and check the student’s level;
- refer to relevant web-pages and topics for further reading;
- highlight the current subjects in the related MECANO newsgroup.
- Using the latest state of the art technology, VRML (Virtual Reality Modeling Language) animations and 3D models are integrated in the web-pages, making MECANO a project which can be put forward as an example in the world of architectural education.

Technically, the database will be consulted by means of PERL scripts via PostgreSQL (ODBC compatible). In this way the project will be completely independent of any operating system, enabling users to choose the hardware and software they wish.

**Fantasy**

Use of this new technology in education gives the student a clear responsibility; it no longer is the institution which decides where, when and how the student takes a course. This asks for a strong backbone, are students up to this?

There are circumstances that might help. MECANO integrates new web-based technology, through the Internet already very popular with students, into education. In this way, the world of education will relate more to the world of the student than it has ever done before, thus increasing motivation. Creativity, flexibility and problem-solving will be encouraged, ‘life-long learning’ automatically becoming a way of life.
As inquiry proved, the final goal for students in the nineties is to graduate. If and when the professional world of architecture asks for specific skills, courses on these subjects are very popular. By means of this new technology, a theoretically unlimited number of students can be admitted to any course, even if not available at their own campus.

But it is no longer 'students only'. The moment the design office is in need of skilled staff and has no suitable applicants, current staff can instantly be given further training by using the new technology. In this way the professional world also fits into the social evolution of 'life-long learning'; the moment that reality fills fantasy.
Computer tools that provide support in the early explorative phase of architectural design are rare. In order to explore the solution space of a design problem, architects in general rely on the use of paper and pencil. We are developing a system which will assist the designer in the exploration of a particular design problem, focusing initially on 2D floorplans. The format chosen for this system is one in which the computer, in interaction with the designer, “evolves” designs.

A major obstacle associated with the use of an evolutionary approach is the adequate representation of a floorplan in a genome. We propose a tree-structure in which the nodes represent organising-principles that dictate how the leaves attached to it are organised. Figure 1 shows an example of a tree with four levels; the terminal nodes represent the elements to be placed. The first level no only represents an organising-principle, but also a contour; this contour is either fixed (e.g. dictated by the environment) or free to evolve. On either side of the tree-structure two interpretations of this tree are shown.
They differ only in the organising-principle at the top level. The interpretation on the left applies a “fishbone” or slicing organisation. In the interpretation on the right, the elements on the first level are organised around a central space. Defining and implementing more of these organising principles, makes this representation very extensible and flexible.

Figure 1.

The evolutionary process is guided by the evaluations made by the computer and the designer. The computer evaluates the designs on objective- and fuzzy criteria. Fuzzy criteria could be evaluated by means of a neural network. The subjective criteria, or criteria that can not be otherwise evaluated, are evaluated by the designer. The general structure of the system is shown in figure 2.

Figure 2.

During the evolutionary process, there are interaction points at which the user is presented a number of alternative floorplans which have a high score on the objective and fuzzy criteria. The user can than alter (augment or decrease) these fitness values, thereby steering the process in the desired direction. Given the same input, the system is able to generate a different solution every time it is run; the random starting conditions make it very likely that the process will converge on another solution with approximate equal fitness.

The working method associated with the system is by no means restricted to the generation of floorplans. An obvious extension would be the development of 3D organising principles in the tree representation. By extending the system to a 3D environment, it could also be applied in, for example, an industrial design setting.
Up to now, we have developed the computational architecture and the algorithms. The next step is the actual implementation in C for Windows 98. Afterwards the efficiency and effectiveness of the tool should be measured in the laboratory as well as in the practice of the building and urban design office. The proposed software does not impose a working style to the designer, who is free to use it in any specific designing strategy, based on the emphasis given to the Concept, the Programme and the Site (see also Van Bakel, 1995). Because the software does not claim expert sketching, drawing or modelling skills, it is especially apt for Computer Supported Cooperative Designing (CSCD) with non-designers like clients and users. Moreover the program allows dynamic planning making use of a strategy of broadening the solutions field repeatedly. This strategy is aimed at creating a series of alternatives instead of the usual exploration in depth of only one alternative. But because the design approach proposed here is build up from the content to the shell (from lay-out to volume) it still needs a complement with an appearance oriented software package (like Xfrog) working from the shell to the content.

Reference
A didactical strategy for teaching architectural design theory and methods

Keywords: Architecture, teaching, design theory, design methods, didactical approach, evolutionary design

This abstract describes a course in design theory and methods for students in architecture. It deals with the principles of Morphogenetic Design, in a didactical setting.

The course is special in the way that theory and methods are not being taught formally, but discovered by the students themselves. The mechanism for acquiring this knowledge is by means of a series of exercises the students have to carry out. Each exercise is put before the students with a minimum of explanation. The purpose of the exercise is explained afterwards, making maximal use of group discussions on the results of the exercise. The discussion is being focused on comparing the similarities and differences in the variants the students have produced. The aim of the discussion is firstly to discover the structural properties of these variants (the theory) and secondly to discover the most appropriate way of establishing these structural properties (the methods). The variants have come on the table by means of the group effort. The habitual reluctance of architects, when required to produce variants, is thus being overcome. Morphogenetic themes like creation, evaluation and selection are being dealt with in a natural way.

The course was developed after experiencing a number of unsuccessful teaching attempts. At first the course followed a conventional pattern in which theory and introduction of methods preceded the exercises. This did not work as theory and methods turned out to remain too abstract for fruitful application. Reversing the routine of the course by strating off with the exercises, theory and methods were understood immediately as their purpose had become evident. This meant as well, that the
discussion could home in on the real issues, rather than remaining on the superficial level of the relevance of theory and methods for architectural design, as is so often—and so frustratingly—the case.

The framework of the course is formed on the ideas of the SAR, the Foundation for Architects’ Research. The SAR has proposed to distinguish in the planning process a number of separate design levels. These levels should each have an intrinsic architectural and socio-economic identity, thus serving as separate realms of decision making and responsibility. A plan on a certain level should allow plans of a lower level to be accommodated. These subsequent plans may even be the responsibility of others clients and architects. Therefore, a general requirement of plans is, that they should be open to further design decisions and should be evaluated accordingly.

The idea of open planning in architecture has proved to be extremely difficult to understand and adopt by architects, as it departs so dramatically from conventional design practice. In conventional practice, architects are not accustomed to working in an open planning environment. Consequently, the ideas of SAR have led to much heated debate, more often than not with as its outcome, that these ideas were being dismissed as impractical and too far removed from reality.

In the course that will be described, this debate is by no means being evaded, but neither does it interfere with the acquisition of knowledge and experience. In fact, the special strategy adopted by the course, tends to de-politicise the debate, placing it firmly in the realm architects should be dealing with, i.e. the architectural consequences of architectural decisions.
The use of evolutionary algorithms to optimise designs is now well known, and well understood. The literature is overflowing with examples of designs that bear the hallmark of evolutionary optimisation: bridges, cranes, electricity pylons, electric motors, engine blocks, flywheels, satellite booms - the list is extensive and ever-growing. But although the optimisation of engineering designs is perhaps the most practical and commercially beneficial form of evolutionary design for industry, such applications do not take advantage of the full potential of evolutionary design. Current research is now exploring how the related areas of evolutionary design such as evolutionary art, music and the evolution of artificial life can aid in the creation of new designs. By employing techniques from these fields, researchers are now moving away from straight optimisation, and are beginning to experiment with explorative approaches. Instead of using evolution as an optimiser, evolution is now beginning to be seen as an aid to creativity - providing new forms, new structures and even new concepts for designers. In the Department of Computer Science, University College London, research is concentrating on these avenues. We are investigating the capabilities of creative evolutionary design, examining how evolution can generate its own representations of designs by evolving developmental processes. We are applying evolutionary design techniques to architecture, showing how evolution can provide many alternative and useful designs, with explanation and justification to clients. We are investigating how evolution can suggest alternative pipeline designs, and how aesthetic cars can be evolved, 'inspired by' many existing models. Nevertheless, despite the blossoming research at UCL and other departments around the world, there are few major collaborative projects for evolutionary design. Currently, Napier University's EvoNet and its sub-group 'EvoDes' provides the only major example of a network on this subject, but its activities seem to be limited to optimisation and engineering. Clearly there is a need for a larger-scale network with a much broader outlook, which should be formed with the specific aim of promoting the dissemination and growth of research in this area. I would encourage a carefully thought out plan with clear objectives and aims. I suggest the following:
1. **Dissemination.** The creation of a network designed to encourage transfer of knowledge between evolutionary design researchers. Regular workshops and conferences hosted by the different members of the network would aid in this, but perhaps the most useful medium would be the internet, with the creation of a web site, comprising archives of papers, code, lists of researchers in this area, and an electronic mailing list.

2. **Advancement of research.** Specific targets should be set to start up new collaborative research projects between different members of the network. For example, each member should provide details of their interests and funding requirements, and members should suggest sources of funding. Dates should be set for proposals, and adhered to. Information about industrial partners who are interested in collaborating/sponsoring research in this area should be shared amongst members.

In order to promote the growth of research in this area, we must stop working in isolation and start to form coherent and directed plans for future investigations. If this can be achieved, then perhaps a 'European Network on Evolutionary Design' could lead the world in the investigation and exploitation of this promising new way to aid designers.
Computergestützte Planungs- und Entwurfsmethoden
Medienexperimentelles Entwerfen in Architektur und Stadtplanung
Programmierte Wachstumsprozesse auf städtebaulicher Ebene in Virtual Reality

Überblick - die in den Vorstudien entstandenen Strukturen
Morphogenetic Design, Generative Design, Evolutionary Design. Or Argenia, the new word that I have conied. The question might be: is this approach a different tool in design? My idea is that the morphogenetic approach can realize operative meta-projects that are new design products. These are something like idea-products, plus these are able to generate an endless sequence of object-products. The idea-projects create a new market: an industry can buy a morphogenetic idea-project of lamps, for example, and use the endless sequence of generated 3D models to produce always different lamps (the idea-project can be used as auto-reprogramming tool for robots). The customer can choose his unique object by activating, in Internet, the generative tool and sending his request to the industry.... or..... a Mayor can order the idea-project of evolution (this means an increasing complexity) of his town and use it to control the incoming possibilities and the identity in progress of the environment.

Three topics: complexity, subjectivity and recognizability.

1. The complexity. The true opportunity is: with Morphogenetic Design we easily can control the complexity, because it is natural to stratify performed procedures belonging also to different fields, and it is a little more hard to stratify performed shapes.

2. The complexity is strongly linked to subjectivity. Subjectivity opens new fields to increasing complexity. Complexity gives to subjectivity the possibility to explain the idea. The challenge is to perform a control system of the complexity that can use this evolutionary system as sequences of opportunities to explain the idea and making an effort to identify and recognize the design.

With this generative approach we can organize a choice of different possibilities but we have to be conscious of our choice, so our work is more complex (but more interesting) and we can even generate an unpredictable formalization but belonging to a well identified, cultural and our subjective idea of architecture.

3. Morphogenetic design is the design of a process able to generate a sequence of events. Each one is different but recognizable as belonging to a species. For this reason the control structure of recognizability of species becomes necessary in this approach. The recognizability of the idea is the
peculiar field of Generative Design, and it is the field that defines the design work, the touch of the designer. The recognizability of the idea is the first step to reach the possibility to sell the idea-product, performed as morphogenetic project. We will present our morphogenetic design experiences, and the generation, in real time, of industrial objects, architectures, town environment.