ENGAGING INTUITIVE VISUAL THINKING
IN URBAN DESIGN MODELLING:
A REAL-TIME HYPOTHESIS

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ABSTRACT

This paper will present prototypical software being used in the teaching of urban design to students and for use by professionals in the early stages of a project. The system is intended to support a heuristic approach to design. That is, it supports a process of refining ideas and understandings through a process of trial and error. The support or aid to design comes in the form of a didactic real-time programme. Its power lies in its ability to provide instantaneous response to operations on the data that can allow one to develop three-dimensional spatial ideas in an intuitively driven manner. This condition appears to occur for both novice and expert computer operators.

The presentation will present our experience to-date in using conventional computer graphic tools to represent design ideas and contrast it with a video demonstration of our prototypical dynamic urban design modelling software for the Silicon Graphics IRIS computers [1].

AMPLIFYING OUR CAPABILITIES IN DESIGN THINKING

Environmental design requires the integration of massive amounts of information and the creative, selective combination of that information to produce better design. It is our experience that new knowledge and creative alternatives to development are extremely difficult to incorporate into real projects and conventional design studio teaching without compromising the attention paid to previously recognized issues. Coping mechanisms in normative design thinking used in most teaching and professional practice are typically stunted to the linear.

Normative design thinking as it is practiced in the various forms of design implies that with adequate skill, education, and experience a person can process and access enough knowledge to be able to conceptualize a problem and synthesize a solution. The reality of practice today is that without technological assistance in the acquisition of knowledge one has little opportunity to comprehensively test the adequacy of new ideas. In our opinion, information technology is needed to assist in the storage, communication and operation on design knowledge.

The opportunity exists in a computing environment to manipulate data and translate ideas about something in a vast array of representations. This scope should help us extend the brain's capacity to synthesize complex amounts of data and differing interpretations. The
further development of this perceptual prosthesis may help people to understand and predict the implications of design actions on the complex environment we live in.

VISUAL COMMON SENSE: MAKING THE COMPLEX SIMPLE

We have done a series of projects over the past few years where we have used computer graphics to create unique visual experiences that have focused and amplified the vision of professionals, clients and the public about particular design and planning proposals. We have used a wide range of very effective tools to visualize complex phenomena and ideas [2]. Some of these tools allow us to produce conventional types of visualization faster and with greater accuracy, others have permitted the visualization of concepts impossible to create any other way. Samples of the types of information that the computer has been useful in communicating about real world professional designs are illustrated in figures 1 - 4. The projects undertaken by the lab were carefully picked to test the computer graphic tools on a variety of applications and on problems of some professional significance. Projects include;

1- An urban design massing study and visual impact assessment of alternative schemes for the creation of extra office space around the Parliament Buildings in Ottawa, Canada (Prepared for the National Capital Commission)(figure #1).
2- A series of site design scale images are illustrated of a proposed detailed street furnishing proposals for the Ceremonial Routes in Ottawa (National Capital Commission)(figure #2).
3- Evaluation of four architectural submissions in the Canada Lands competition in the City of Ottawa, Canada, (Prepared for the City’s Planning Department) (figures #3 - 4).

fig. #1 Parliamentary Precinct, Ottawa : The first proposal on the left focused visual attention on the Mackenzie Tower and placed buildings on the banks of the Ottawa River. It was not until the planning team saw the image on the right that it was clear to everyone that the view to Parliament was more important and warranted reducing the density of building on the site despite the need for more office space.

fig. #2 Ceremonial route, Ottawa : These images illustrate the evolution of a particular street tree planting strategy. The image on the left shows an interplanting of hybrid poplars and red oak 5 years after planting. The image on the right illustrates the same scene in 30 years when the poplars have been removed.
fig. #3 Can Lands Competition Evaluation, City of Ottawa. This work involved digitizing a polygonal model of four short listed entries using AutoCAD. The polygonal models were transferred to an IRIS 8000 workstation for the creation of shaded colour still images and dynamic wireframe walkthroughs of each proposal. The four images above illustrate exterior paving, terrain, ground floor land uses and pedestrian linkages. The ability to portray the spatial geometry of abstract design considerations proved to be a unique and valuable addition to the traditional information available to the evaluation team.

fig. #4 Can Lands Competition Evaluation, City of Ottawa: Integration of traditional perspective views with the spatial representation of the zoning envelope restrictions. Those parts of the scheme that violate the zoning appear as protrusions in the image on the right.
IMPROVING STUDENTS PERCEPTION OF THEIR DESIGN IDEAS

Our goal in using computers in design studio teaching is to extend the vision a student has of the problem they are working on and to maximize their capacity to experiment and correct mistakes. It is our belief that if a student can intelligently learn from mistakes that they can compress the time necessary for them to develop an adequate level of experience with a problem. They can come to know something through a process of dialogue and intense experience. It is our goal to compress these heuristics with the use of computing tools.

If one can be engaged in a process of examination and manipulation of design concepts that occur in a spontaneous, "natural" way, then we find that one's ability to receive knowledge by direct perception, to intuit, is enhanced. Computer graphics can assist in the process of representation. They can support the mind with a variety of means of visual representation of the same thing and help to structure the mind's powers of imagination, description, and portrayal [3].

We believe that we have successfully applied computer graphics to the problem of improving our students perception of their work. Figures 5 through 8 illustrate a sampling of computer graphic techniques used by our students to visualize design ideas. Studio teaching staff at the school have observed that students in the computer studio are developing skills in the accurate translation of schematic diagrammatic ideas into three dimensional form sooner than occurs using traditional visualization methods.

**PHILOSOPHER'S WALK**

**AREA ANALYSIS**

**fig. # 5:** an example of a project summary sheet given to critics by a student at final presentations. The student attempted to integrate the output of several different programms and machines. Text, and spreadsheet space planning comparisons were prepared on a Macintosh, terrain and building models were constructed in AutoCAD on an IBM-AT and displayed in 3D on a Macintosh emulating a Tektronix 4014 logged into an Iris.
fig. #6 An idea quickly rejected by a student once he saw how his idea had translated from plan.

fig. #7 An example of students using a targa16 board on an IBM-AT to visualize a new building proposal on Philosophers walk on the University of Toronto campus.

fig. #14 shows examples of manual drawing over three-dimensional wireframe perspectives. The left hand image is a conventional pencil rendering on printed output and the right hand image was created on a Macintosh on top of a captured perspective wireframe.
However, in most circumstances the process of testing an idea takes as long for the student as the process of building a physical model or drawing a perspective. In practical terms, they often cannot test their perception of a scheme in the time frame given for the exercise. Existing computer graphic tools do little or nothing to support a process dependent on making many errors [3]. With this in mind, we are trying to get our computer graphic tools to cycle as quickly as the design process we use demands.

**MODELER: COMPRESSING A WEEK'S WORK INTO TWO HOURS**

Expert users still have to devote too great a percentage of their mental concentration to the operation of the graphic information systems we use. They should allow one to concentrate judgement and creative thought - not compete for it [6]. We have set out to create an urban design system that allows one to intuitively pursue form studies on a computer. Our goal has been to accomplish in a couple of hours what has been taking us several days to do using conventional programmes with experienced users. To create a system that handles most of the analytical and visualization activities that rob one's concentration during the early stages of an urban design massing exercise. A computer should allow us to work with a range of visual representations of an object or space. One should be able to choose to operate with symbolic, abstract or detailed representations in a picture. There is a rich potential if we can rapidly switch between an infinite variety of visual information modes to support whatever type of inquiry the operator of the computer feels necessary.

**INTEGRATED REPRESENTATIONS OF URBAN DESIGN IDEAS**

The prototype software developed at the university, allows one to not only manipulate built form dynamically in shaded colour images, but to also provide real-time feedback of planning information such as economic costs and floor-space-index as one adds or subtracts space to a building with a movement of the computer's mouse. This programme is also being used in the planning of the Bathurst-Spadina Neighbourhood on reclaimed rail yards in the City of Toronto with Jerome Markson Architects.

The programme is composed of four types of graphic representation. The primary window on the data is a three-dimensional perspective window that illustrates the exact geometry of the objects and spatial constraints such as zoning setbacks on each parcel of land. The observer has complete freedom of movement through this view of the geometric "world" shown on the screen (refer to fig. #9). The second window on the data is a "spreadsheet" window that provides alpha-numeric parameters of the buildings and conveys zoning information such as density ratios. The third window is a diagrammatic representation of the database hierarchies. Some re specification of relationships between components of the massing models can be undertaken using this view of the data (refer to fig. #9). The fourth type of representation are two dimensional views of the geometry such as a plan. All of these views run in real-time. A change in one mode instantly updates all of the others. The system imports AutoCAD DXF files to begin a session and ends the session by exporting either an AutoLisp file that can build the data as an Automated session in AutoCAD or in the data format used in our lab for other graphics software we have written [1]. The land parcel information illustrated in figures #10&11 was created by importing survey data in AutoCAD supplied by the consultant's surveyor in the Bathurst-Spadina Study.

This tool has been used to successfully generate volumetric massing studies by a variety of people that have never used a computer before. Professional designers involved in the study have been able to operate the system effectively within a few minutes of being introduced to it with no manuals or tutorials (see fig. #11). We have had similar success with the system in a variety of teaching situations where software was ported at other
fig. # 9 The left hand image illustrates a portion of the primary perspective window with the second "spreadsheet" window also shown at the bottom of the image. The right hand image shows an example of the diagramming window. This window shows data base relationships and provides some tools for changing relationships.

fig. # 10 The left hand image shows the fourth type of two-dimensional plan. The right hand image shows an AutoCAD base drawing for the site that can be transferred to the modeller on the Iris to produce a base model to begin a modelling session. Once a scheme has been developed the user can save a version of the model in an AutoLISP format to reconstruct the geometry in the CAD system or as a polygonal model for use in a rendering programme.

fig. # 11 The left hand picture illustrates a preliminary massing study prepared during the Bathurst-Spadina Neighbourhood study in the City of Toronto. The picture on the right shows a scheme transferred into AutoCAD, integrated with a terrain and context model of Toronto and transferred back to an Iris 3020 for rendering.
schools. In all cases, a five minute demonstration combined with a few minutes of direction from a familiar user is all that is necessary to get people started. It has proven particularly useful for introducing the principles and parameters of urban design to students.

We believe that the key to this success lies in the semantics of interaction and the extremely fast response to users inputs that the Silicon Graphics IRIS computers are capable of providing. The dialogue a user has with the system is not the obtuse language of computer graphics or computer-aided drafting. Typical graphics systems use a vast array of strange terminology to a designer. Terms such as translate vertex, or rotate line about the xz axis are extremely common. Even when these operational concepts are expressed as graphic icons, the array of options is confusing to most people we encounter. In order to operate typical modelling software one must first, develop an understanding of the language of the system and then formulate a strategy to marshal the graphics tools to construct a collection of graphics entities such as lines or polygons to adequately represent the idea that one has. Their difficulty for the user is that the user is forced to undertake all or most of the translation of ideas into a computer form for the programme and unless the user has a deep understanding of how to harness the system, one will find it very difficult to use the parametric capability of the system if their conception of the design idea changes during the session. A change of that type normally requires a complete recrafting of the data base used to create the graphic representation on the screen.

The interface design for this massing modeler attempts to remove from the user the burden of translation between design ideas and the specific demands of computer graphic semantics necessary to construct an image. It uses constraints on types of geometric operations and attempts to use the everyday language of an urban designer to get the machine to change the image. In addition, hand gestures with simple pick operations using the computer's mouse are used wherever possible. We are trying to simplify interaction to a set of elements familiar to the user. The simplicity of action is matched with the extremely sophisticated capacity of the IRIS computer to handle three-dimensional graphic computation in real-time.

MAKING IT EASY TO CORRECT MISTAKES

The hypothesis of this interface is that since most learning in design occurs through a heuristic process (trial and error) the best way to introduce people to the tool is to make it easy for people to correct mistakes by allowing them to use the cognitive understandings of space and modelling that they already have in place. We have discovered that by supporting the process of learning about spatial modelling through trial and error where the person learning is directed as much by their immediate feelings or intuition as by the structure of the system. And the structure imposed by the system is a language specific to design not computer graphics or drafting. The user has complete freedom to use intuitive curiosity about the forms generated limited by the didactic structure imposed by the urban design semantics of the modeler's interface.

The three buttons on the computer's mouse are used to govern the fundamental mouse interactions. The left button is used to pick menu options or highlight a building or parcel of land to be operated on. Movement of the mouse while holding down various button combinations produces parametric scaling or move operations on the object. One switches between move and scale operations by toggling the space bar. These operations occur in "model" mode. In "move" mode the mouse buttons are used to move the viewer through the spaces of the model. Most people can master how to interact with the programme in the first few minutes of experimentation. Feedback to the user is instantaneous so most people can correct a wrong movement before they are even conscious that they are correcting a mistake. Conventional computer-aided design systems require that one stop the operation
fig. 8.12 The following images illustrate stages of a typical modelling session when we introduce principles of urban design massing. In the left hand picture the parcel to be operated on has been touched with the mouse to highlight it. The setbacks menu has been activated and the setback and height constraint envelope parameters are created. Finally, in the right hand picture a building block has been set on the parcel. These blocks begin as 10 m. by 10 m. by 3 floors.

fig. 8.13 In the left hand picture the block has been dynamically scaled or "slewed" with the mouse and floors added to its height. The activated menu shows the floor interval being toggled. The right hand picture shows a simple model typical of what people generate in the first few minutes of an introductory exercise. The dynamic spreadsheet tables below provide instantaneous information on density and floor area as they experiment with massing alternatives.

fig. 8.14 These two pictures illustrate eye-level views of a model that one can move through dynamically. The right hand picture shows the zoning constraint envelopes. When enabled, the constraints prevent buildings from being sized or moved outside the envelope.
and invoke an undo operation if experimentation is attempted. This typical interface design rewards those that know what they want to craft before they begin to craft it. This self limiting condition prevents the computer from being used to widen the scope of design speculation.

ADAPTING THE CONCEPTS FOR POLYGON DISPLAY TECHNOLOGY

Given the success of this prototype with our users we are in the process of trying to generalize the concepts and not make the package specific to rectilinear urban design massing. The first step will be to extend the scope of the tool from massing to the modelling of abstract and detailed representations of specific buildings on full three-dimensional terrain. This capability requires that the computer we use move from a 1000 shaded polygon per second draw rate (as illustrated in the left hand picture in fig. #15) to a 20,000 - 100,000 polygon per second draw rate (as illustrated in the complexity of the conventional still rendering on the right hand side in fig. #15) in order to convey the appropriate amount of visual information necessary to visualize this type of problem in real-time.

![Fig. #15 The version of the modeler shown in the left hand picture can only run in "real-time" with right rectangular geometry, a flat site and a limit on scene complexity of about a 1000 polygons. The operational version of the modeler currently under development will be capable of operating on three-dimensional terrain and arbitrary polygonal models with scene complexities ranging from 10,000 to 40,000 polygons. The right hand image is typical of what the new system can represent in "real-time" (1 frame/sec.)](image)

The second step in our work is to extend the range of types of visualization available to the user. We believe that the the addition of a powerful diagrammatic editor/modeler is critical to a robust visual thinking environment. It is necessary for a designer to be able to develop ideas and arrange concepts as notes, numbers, graphics symbols, 2-dimensional diagrams & drawings, 3-dimensional diagrams and perspectives, and to simulate processes [4]. This approach to using computers is only just becoming feasible to explore. Intuitively driven 3-dimensional modelling is only now a viable activity on two or three high performance professional workstations such as the Silicon Graphics 4-D computers. It is our contention that these machines can provide 3-d images conveying significant amounts of visual information fast enough to support sub-conscious iterative design. In our experience, the feedback interval using static 3-dimensional information has been ponderously counterproductive to creative thought.

The third step in the project is the combination of these capabilities into a spreadsheet-like set of integrated tools for a designer. It is our contention that unless CAD integrates both systematic and intuitive operations on data then it is not CAD.
A DYNAMIC SUPPORT TO THOUGHT

This work explores a real-time hypothesis. It is our contention that the user of a computer should not be hindered or devote a significant amount of mental energy to the translation of basic ideas into computable form. The machine must be a useful support to dynamic thought before it can radically alter the practice of design thinking.

The modeller prototype has provided us with instantaneous response to operations on the data that has allowed us to begin to develop three-dimensional spatial ideas in an intuitively driven manner. This is the first time that we have been able to engage such mental faculties while working on a real project in front of a three-dimensional computer modelling system. We believe that the costs of the hardware required to implement this capability will be comparable to the cost of systems currently being purchased for drafting functions. Once that cost threshold is crossed we believe that computers will be used at all stages of design thinking.

ACKNOWLEDGEMENTS

The author would like to acknowledge the extraordinary contributions of Shannon McKenzie and the assistance of Stephen Ginsberg and Mike Paper in the development of our system. We would also like to thank the members of the Dynamic Graphics Project of the Computer Systems Research Institute for their assistance in the development of software used in these projects. We would like to recognize the innovative efforts of the many students and design professionals that have worked on the projects illustrated, Robert Allsopp, Peter Smith, Micheal Hough, Denis Major, Patrick Chen, Stephen Ginsberg, and Ronji Boroush. Major funding for the activities of the lab has been provided by Alias Research Inc., Silicon Graphics Inc., and The University Research Incentive Fund of the Province of Ontario.

REFERENCES

[1] colour reproductions of previous project work and the urban massing modeler are presented in; John Danahy, Robert Wright, Exploring Design Through Three-Dimensional Simulations, Landscape Architecture Magazine, the American Society of Landscape Architects, July/August 1988.


[4] note we define real-time for design as being one iteration of a picture per second, our experience to date shows this as a typical threshold where machine lags interfere with most of our designers natural thought process. This work is documented in;


[6] We were inspired to try the URBANS experiment again but not in hopes of creating a partner for the designer, simply a powerful visual medium linked to computation. N.Negroponte, The Architecture Machine, MIT Press, 1970, Cambridge Mass.

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