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More often than not, discussions taking place in specialised conferences dealing with computers and design tend to focus mostly on the tool itself. What the computer can do that other tools cannot; how computers might improve design and whether a new aesthetic would result from the computer; these are among the most recurrent issues addressed in those forums. But, by placing the instrument at the center of the debate, we might be distorting the nature of design.

In the course KEYWORDS, carried out in the years 1992 and 1993 at the ETH Zurich, the goal was to transcend the discourses that concentrate on the computer, integrating it in a wider theoretical framework including principles of modern art and architecture. This paper presents a summary of the content and results of this course.
introduction

It is our contention that a theoretical discourse focused only on the instruments—in our case, the computer—might distort and simplify design. It might distort it because it implies that one of the goals of a design is to justify the potential of the tools employed to conceive it. In effect, it is not unusual to find in the specialized literature statements such as: "this could only be done because of the computer." This sort of statements convey a value-judgment about the computer capacities. Indeed, what it is meant is that the efficient (e.g., rational, economic) solution has been possible because of the computer, or the complicated form could have only be made with the computer. This way, issues which lend themselves to computer implementation become central to the design (an efficient plan distribution, a complicated geometry), sometimes in detriment to other design issues which cannot be easily transposed onto a computer (e.g., subjective dimensions of form, involving symbolic or aesthetic values). Therefore, a discourse centered around the instrument alone simplifies design because, by focusing only on the tool, other important factors that influence design might be underestimated or even neglected.

Design embraces a whole complexity of issues that are relevant to a culture at a given time. Today's computer technology is one of those issues that design should embrace, but it should not be the only one.

teaching design with computers

Within the context of architectural design education with computers, discourses which concentrate exclusively on the tool might be particularly misleading. Results created in a design studio using computers can hardly ever be attributed only to the capacities of the media. There are always other issues involved which, even though they are not always explicitly mentioned, influence design as much as the tool might do. Two of these elements are particularly important: (1) the conceptual paradigms, ways of thinking of architecture predominant in a particular moment and time. This includes predominant theoretical discourses as well as images of influential designs, both from the present and from the past. Ideas and images that are always around in the design studio, permeating everything we discuss and produce; and (2) the personal factor. This includes the personality, cultural background and affinities of the students, their particular design talent, the interaction among them, as well as the capacity of the educator to build up a conceptual framework within which students can develop creatively their ideas.

KEYWORDS: modern art and the computer

In our view, in a design studio with computers, discussions should not be restricted to technological issues, but they must transcend the tool and get to the conceptual issues involved. Accordingly, the task of the educator is to unveil those issues and to present them to the students in a structured conceptual framework within which they can develop their work.

To create such a framework, this was indeed the main purpose of the course which under the name of KEYWORDS took place in the Summer semesters of 1992 and 1993. A basic premise of this course is that there exists a strong link between some fundamental principles of Modern Art and Architecture and the intrinsic representational capacities of computer tools.

KEYWORDS stand for eight categories which built up the theoretical content of the course: composition, construction, space, object, type, system, method, and representation. Each keyword stands for a conceptual paradigm with which to analyze some of the aesthetic principles of modern art and architecture of the beginning of the century in Europe. The principles which we were interested to explore where those for which we could find a counterpart in the representational capacity of computer graphics tools.

The course is structured in two parts. The first part consists of three short exercises corresponding to each one of the first three keywords. These are exercises in abstract compositions, in two and three dimensions. The goal of the second part is to design an architectural object, having a specific program and site. The remaining five keywords provide the conceptual paradigms to be used in the architectural design process.
modern art, architecture & the computer

In the first three chapters, composition, construction, and space, we discuss common points that could be found between some of the most relevant works of modern art and architecture of the early twentieth century (e.g., compositions of Van Doesburg and Mondrian, constructions by Klutsis and Lissitzky, buildings by Van Eesteren and Van Doesburg) and the computer graphics tools. These points of contact can be summarized as follows:

- **Geometry as formal language.** The compositions of Van Doesburg or Mondrian are combinations of lines and surfaces placed in an abstract space. Each formal configuration is one among many possible ones. Combinations are endless. A formal vocabulary based on geometric figures and the possibility to combine them in endless ways are indeed characteristics of computer graphics programs.

- **Concept of space.** A unique concept of space pervades in the works of modern painting, sculpture and architecture. The counter-constructions of Van Doesburg, the chair of Rietveld and the house of Mies, are all the expression of an abstract, cartesian space that exists independently of the elements placed in it. This is precisely the concept of space embodied in a computer graphic program.

- **Relation between abstraction and reality.** In the avant-garde painting of the beginning of this century, the relation between reality and representation that had prevailed since the Renaissance began to change. Representation no longer needed reality. Moreover, representation took over reality. In the Selection of Materials of Tatlin, the objects project out of the canvas to become part of the reality. The prouns of Lissitzky also suggest a exchange of roles between abstract and real. A building like the Barcelona pavilion from Mies van der Rohe seems to belong more to the world of abstractions than to reality. It is a materialized abstraction. Reflections and transparencies contribute to give the impression that the building does not belong to reality but the world of illusion. Exchangeability of abstraction and reality, and substitution of reality by illusory
images are also characteristics of the works created on the computer.

- **Abstract nature of modern architecture.** Buildings in the classical period of the Modern Movement were conceived as pure volumes. After being built, they kept looking as enlarged objects, rather than buildings. A transformation of a building into an object, and the subsequent loss of scale, takes also place in computer modelling.

- **The issue of representation.** Ultimately, the most significant achievement of modern art and architecture was the elimination of the barriers that separated the different arts. The field of action of the modern artist was not restricted to painting, sculpture or architecture. Rather, the field of representation was the unique territory where the modern artist created. With modern art we became aware that representation is the key issue of artistic creation. It is also the key issue in the creative work done with computers.

These issues were brought up in the corresponding lectures, and provided the theoretical background for the students to carry out the exercises. The goal of the exercises was not to redraw or remodel relevant works of modern art and architecture. Rather, students were expected to come up with their particular interpretation of the principles embodied in those works, and to apply them to create new works.

**composition-construction-space**

In composition, the first exercise, students were asked to re-interpret the pavement made by Van Doesburg in the house De Vionk. The original design of Van Doesburg consists of a vocabulary of color rectangles hierarchically organized. The rules of composition of the original work were understood differently by each student, given rise to new and original variations (Figures 8-9).

More important than the congruency between the original work and the new ones, is the fact that a student is confronted to systematic design thinking with a computer. The work was done with a standard general-purpose CAD program. Match-
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In construction, the second exercise, the students were to create an object which could be both a sculpture and a piece of furniture (or both simultaneously). The works of Rietveld and Vantongerloo, and those of the Russian constructivists Rodchenko, Lissitzky and Klutsis were debated in the class. These works can be understood as creations developed from specific formal vocabularies: the language of the line, the language of the plane, and the language of the solid. In their work with the computer, students were asked to choose the modeling technique that would better fit their design intentions—e.g., wireframe, surface or solid modeling (Figures 10-11).

In space, the third exercise, the task was to create a 3D space using a formal vocabulary of planes, as van Doesburg did in his counter-constructions (Figures 12-13). The focus in this case is not so much on the object itself, a composition of planes, as in the space that results from it. Flat shading renderings in perspective view, and animation programs were the basic computer techniques used for this exercise (Figures 14-16).

After the three short exercises, the next task was to design a more complex architectural object, with a program and site. In the summer semester of 1992, the theme was a private library, and in 1993, a kiosk. The remaining five keywords, object, type, system, method, and representation, stand for corresponding paradigms of the design process. In the lectures, each one of these conceptual paradigms was illustrated with examples of Modern Movement architecture and with contemporary examples (Madrazo 1992). The following is a description of what is meant with each conceptual paradigm, and its connection with the computer:

- **Object** stands for the stage of the design process in which the architect works very much like a sculptor, reducing the scale to an abstraction level that allows the quick elaboration of formal hypothesis. Architects have been
using physical models to design since the earliest times. With a model an architect achieves a quantitative and qualitative reduction of the object which makes design possible (Arnheim 1977). Thinking of a design in terms of object is intrinsic to the characteristics of computer modeling tools. In the realm of computers, architectural works become objects; conceptual objects.

- **Type** conveys a recognition of the inherent structure inherent to a particular form. In architectural theory, type has been understood as the permanence of a form over time; the necessary link between tradition and modernity. Such was the idea of type present in the theories of Durand as well as the most recent ones of Rossi. This internal structure does not have to be derived necessarily from precedents. Within the restricted context of the architect’s own work, type can be understood as the internal structure or schema to which a particular design adheres. To design with computers, it is crucial to be aware of the internal structure of the object, in order to represent it with the techniques that the computer tool provides.

- **System** is tantamount to seeing a design in terms of relation form-context. After becoming the predominant paradigm in the biological sciences during the nineteenth century, the idea of system has become part of the conceptual apparatus of the modern conception of architecture, from Semper to Le Corbusier. According to this paradigm, form is seen as a state resulting from the interaction between form and context. This dynamic view of design, according to which the different stages in the process of design are assimilated to a form in continuous stage of transformation, lends itself to various kinds of computer implementation.  

- **Method** conveys the idea that design might be thought of as a step-by-step process, which could, potentially, be formalized on the computer. Design methods in architectural design have been advocated since at least the time of Durand. In our times, the notion of design
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Summer Semester 1993.

method was strongly defended by some theorists in the sixties, and has become the central theme of the work of architects like Peter Eisenman. Working in a sequential manner is intrinsic to computer tools. Forms represented in a computer modeling program are always the product of some sort of method. In solid modeling, for example, a complex form can be the result of applying boolean operations onto a set of geometric primitives.

- **Representation** can be understood in two ways: as the conceptual system within which the idea is conceived, or as the medium through which is to be visualized. There are cases in which it might be difficult to make a clear distinction between these two dimensions of representation. For example, sketches are often used to both conceive and communicate an idea. In other cases, a medium might be used to communicate the idea, but not necessarily to conceive it. This is the case of computer models and animations, when their use is limited to re-present what has been conceived previously with other media.

**Discussion of the results**

The results produced by students in these two courses gives us a chance to assess the validity of the previous design paradigms, and to discuss in which way the adherence to a particular paradigm has influenced the final design. The first two examples belong to the semester of 1992. The design project was a private library, adjacent to an existing Palladian-like villa located in the outskirts of a small town near Zurich.

The project in Figures 17-21, makes it a case
for two design paradigms: object and representation, in the conceptual sense. The student understood this design mostly as an abstract object: a curvilinear structure, modelled after a Moebius band, held the bookshelves and corridors giving access to them. The structure was partially modelled with an AutoLisp subroutine, that created the Moebius line. This curvilinear object was placed inside a cubic box, with the entrance located at one of the corners. The contrast inside/outside was made evident with the use of two opposing geometries: the rectilinear form outside, and the curvilinear inside.

The project in Figures 22-27 exemplifies the paradigms of system and representation. The library is buried in the ground, with the main space having the form of an inverted, truncated cone. This space is traversed by a circulation system composed of ramps. The space is covered by a radiated structural frame. Each one of these sub-systems (cavity, ramps, frame) could be detached from the whole and still function in isolation.

The eminently dynamic character of the spaces created was properly represented through an animation. The movement through the ramp brings about a sequence of continuously flowing spatial impressions reaching its climax in the interior of the inverted cone (Figures 22-25). From that moment, the camera, influenced by the geometry of the space, begins to move in circular patterns (Figures 26-27).

The next two examples correspond to the semester of 1993. The theme was a kiosk located...
at Paradeplatz, one of the most representative places in Zurich. The kiosk holds different functions: press stand, ticket office for public transportation, public toilets and waiting areas. Context was expected to play an important role in the design. First, there was the precedent of the existing kiosk, to be replaced with the new design. Second, the characteristics of the square: the adjacent facades, with a diversity of styles, defining the spatial volume where the object would be placed; and the patterns of movement of pedestrians and public transports on the surface.

Object and type were the main design paradigms adopted in the design of Figures 28-31. The student began proposing a simple volumetric scheme, characterized as having head and a tail. The head, containing the press stand, was placed at the point of tangency of the square with the adjacent main street, where the flow of pedestrians is more intense. Hanging from this head, there is a linear structure penetrating into the space of the square. This part is triangular in plan, so the building becomes smaller as it goes away from the head. A glazed canopy, which evokes a similar feature of the existing kiosk, extends from the triangular core, as wings that stretch out to give protection to pedestrians.

This design, therefore, needs to be understood as the response to the particular conditions of the site (spatial flow, precedent). But it was also influenced by a design for a kiosk for the Electra publishing company, designed by James Stirling, which was presented and discussed in the corresponding lecture. It is the underlying scheme, or type, which the student’s design shares with the design of Stirling. It can be contended that the basic idea of this design was present in the early volumetric scheme, made with a computer modeling program. The simple initial model contained already all of the design issues at stake: integration into the spatial flow, distribution of functions, reference to precedents. From this point, the design proceeded as a refinement process: proportions of the different elements were adjusted, tectonic aspects were brought into consideration, and building components were given more detail. From the point of view of computer modeling, it was necessary to create different versions of the model as the design
evolved. Even though we used substitution of components with different levels of detail as modeling technique to represent different stages of the design process with the same model, this technique has its limitations. At some point, it was necessary to abandon a already existing 3D model and to begin a with a new one.

System is the most dominant design paradigm in the example of Figures 32-35. The motion paths of the streetcars crossing the square bring about an island in the middle, where the actual kiosk stands. The student assimilated the form of this island in plan with the form of a fish. Then, the metaphor of the sea came into play: the roof of the kiosk was assimilated to the deck of a boat, which the passengers/pedestrians could access to gain an elevated view of the sea/square underneath. Similarly, the bunch of slanted columns that traverses the roof was meant to recall similar elements that one might find at the shore, stuck to the bottom of a sea or lake. The computer model was done mostly with solid modeling techniques. Sections extracted from the model were further worked out in two dimensions.

conclusions
The experience of teaching the course KEY-W O RDS two successive years proves that students respond favourably to the attempt to create a unified conceptual framework, encompassing both the principles of modern art and computers. Within this framework, students were able to do creative design using computers in a meaningful way. We see this theoretical context as a guarantee against an indiscriminate, and often meaningless, generation of computer images.

With regard to the second block of the course, that deals with the architectural project, the main challenge is to identify the design paradigm that better fits the design thinking of students. The discussions on different conceptual paradigms proved to be extremely valuable and inspiring for them. This notwithstanding, we cannot expect that all design knowledge is given a priori to students, nor that students should follow, in the strict sense, a design methodology suggested by the educator.

Ultimately, the two key issues in the integra-
tion of computers in architectural design are methodology and representation. The mere fact that the computer forces one to work in a step-by-step fashion necessarily makes the designer aware of the methodology he or she is following. For an architect, designing with a computer means to work creatively within the framework of a given methodology. It is through the method that one can achieve a successful dialogue between designer and machine. The conceptualizations of design described in this paper might suggest some of these methods to work creatively with the computer.

Representation in architecture is the expression of a concept by visual means. Conceiving and visualizing are inseparable moments of the act of designing. Representation, therefore, should not be limited to visualization techniques, but should be considered as a conceptual system with which the idea is created. Much of the novel results achieved by modern artists at the beginning of the century in Europe was the result of operating within a new representation system. The aesthetic of modern art is implicit in the representation itself. In principle, at least, it is at the representational level where computers can influence the conception of a design at most. However, identifying which are the new representational possibilities of the computer, and making an intelligent and creative use of them, is not straightforward. In fact, it is the whole heart of the matter of using computers to design in architecture.

The pedagogic approach initiated with the course KEYWORDS has been further developed later, giving rise to two new courses which are currently part of the postgraduate program of the Chair for Architecture and CAAD. The first is a course, called “Structures,” which integrates painting, architecture, perception, architectural theory, computer graphics and philosophy in five distinct parts, all of them having the notion of structure as a common denominator: text, shape, object, space and light (http://caad.arch.ethz.ch/teaching/nds/ws97). The second course is “Designing with Computers,” which focuses on the application of computers in architectural design, from conception to presentation. It is structured in four stages: mapping, schema, development and presentation. The first two stages deal with the use of computers in the conceptual phase of the design, paying special attention to the issues of methodology and representation suggested in this paper (http://caad.arch.ethz.ch/teaching/nds/ss98_dwc).

endnotes

1 In the early times of CAAD, in the sixties and seventies, design was considered to be a matter of problem solving, and the computer was supposed to be the instrument to create the most rational (e.g. efficient) solutions of those problems. In the meantime, this naive functionalism has given place to an interest for complex freeform constructions which, it is claimed, only the computer can produce.

2 Robert Bruegmann has pointed out a possible connection between the works of Russian constructivists and computer graphics tools. He contends that the work of the Russian artist Chernikov, “in which simple geometric ‘primitives’ are manipulated in fairly simple operations, formed the basis of most computer programs designed for mechanical engineers—which in turn became the basis for the first programs for architects. Likewise Chernikov’s use of brightly-coloured lines, frequently arrayed in dense parallel configurations or grids, is relatively easy to achieve on the computer.” (Bruegmann 1989). Notice that Bruegmann thinks of the computer mostly as a tool which makes easier the task of constructing objects through simple primitives and operations.

3 Lévi-Strauss has referred to the reduction of scale in architectural models in these terms: “The smaller the totality of the object, the less redoubtable it appears; by being quantitatively diminished it seems qualitatively simplified. More precisely, the quantitative transposition increases and diversifies our power over an analogue of the thing, by means of which the thing itself can be taken hold of, weighed in the hand, comprehended with a single glance” (Arnheim 1977:124).

4 John Frazer’s An Evolutionary Architecture is a good example of the notion of system applied to the field of morphology. It is not self-evident though, that the shapes that result from algorithmic processes are necessarily architectural forms.
references


Madrazo, Leandro, 1992. “Keywords: Notes on Form, Space and Architecture.” ETH Zurich.