FULL-SCALE MODELING IN THE AGE OF VIRTUAL REALITY

*Proceedings of the 6th
European Full-scale Modeling Association
Conference in Vienna, Austria,
September 4-6th 1996*

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EDITED BY BOB MARTENS

VIENNA UNIVERSITY OF TECHNOLOGY

DEPARTMENT FOR SPATIAL SIMULATION

IN COLLABORATION WITH THE

INSTITUTE FOR SPATIAL INTERACTION
AND SIMULATION (ISIS)

Cover (image processing): Borislav Petrov

Preface

In times characterized by the growing "architectural criticism" to the same extent as by the helplessness of the anonymous user the communication process between contractors, planner and users gains in importance. If communication is successful will not only depend on the quality of the project but also on the means of conveyance, e.g. visualizing or model representation. Can planning evaluation be effectively supported by virtual reality (VR)?

The principal item of a *full-scale lab* preferably features a court-like facility where the 1:1 simulations are performed. Such lab facilities can be found at various architecture education centers throughout Europe. In the early eighties the European Full-scale Modeling Association (abrev. *EFA*, full-scale standing for 1:1 or simulation in full-scale) was founded acting as the patron of a conference every two years. In line with the conference title "Full-scale Modeling in the Age of Virtual Reality" the participants were particularly concerned with the relationship of physical 1:1 simulations and VR. The assumption that those creating architecture provide of a higher degree of affinity to physical than to virtual models and prototypes was subject of vivid discussions.

Furthermore, the participants devoted some time to issues such as the integration of model-like ideas and built reality thus uncovering any such synergy-effects. Thus some major considerations had to be given to the question of how the architect's model-like ideas and built reality would correspond, also dealing with user-suitability as such: what the building artist might be thrilled with might not turn out to be the residents' and users' everyday delight. Aspects of this nature were considered at the "Architectural Psychology Meeting" together with specialists on environment and aesthetics. As individual space perception as well as its evaluation differ amongst various architects, and these being from various countries furnishing cultural differences, lively discussions were bound to arise.

Some of the events were attended by more than 50 participants, the accompanying students' exhibition on the topic "Parasite Architecture" adding to the attractiveness of the conference. Students' design works "experimenting" on the main building of the Vienna University of Technology were exhibited resulting from a workshop where the architecture of the Biedermeier-building

was altered by (reversible) constructions and objects. The principle "Parasite Architecture" was not to regarded as a negative one, but rather as changing architecture in line with changed requirements and utilizations.

EFA '96 was hosted by the Vienna University of Technology in collaboration with the Institute for Spatial Interaction and Simulation (ISIS). The conference was furthermore supported by the *Federal Ministry of Science*, *Creditanstalt-BV* and several enterprises all of which we render our sincere thanks.

Finally, we take pleasure in announcing the seventh EFA-conference taking place at *Oikos* - Bologna in 1998.

Bob Martens
December 1996

"Institute for Spatial Interaction and Simulation" (ISIS)

Man and space result in an intense interaction. On the one hand specific features influence human perception, on the other hand man impresses on space, changing and shaping it. Scientific research within the field of regional planning and architecture, particularly concerning the relation and interaction field *Man and Space* represents the main focus of the *Institute for Spatial Interaction and Simulation (ISIS)*. By means of visualization and modeling the quality of communication is enhanced. Simulation of space processes with special attention as to applied methods, media and techniques consequently falls within the activities of the institute.

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C O N T E N T S

I REAL REALITY

II ARCHITECTURAL PSYCHOLOGY

I
REAL REALITY

On the Relation of Full-scale Simulation and Virtual Reality

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Introduction: What is VR?

Simulation or in other words, the illusion of reality aims at predicting the impact of an object to be built. The accuracy to be achieved depends on the respective possibilities of use of the simulation media chosen. Great hope is pinned on the phenomena of *virtual reality* in this context. Regarding definition of term we want to point out that virtual reality refers to the reality. The reality is what man meets upon and what he faces whiles planning and designing. Thus a real condition is to be regarded as the pendent to the unreal or ideal condition. Prototyping and modeling are used as working steps throughout the planning activities in order to check the reproduction and the operating execution of an object to be built, of city quarters or of space in planning. The virtual-digital and physical-analogous working levels are of great importance. The physical model in full scale acts as substitute for the original and is to outline the proximity to reality. The virtual model has the capacity of "acting", e.g. the reality appears by virtue even in absence of physical matter.
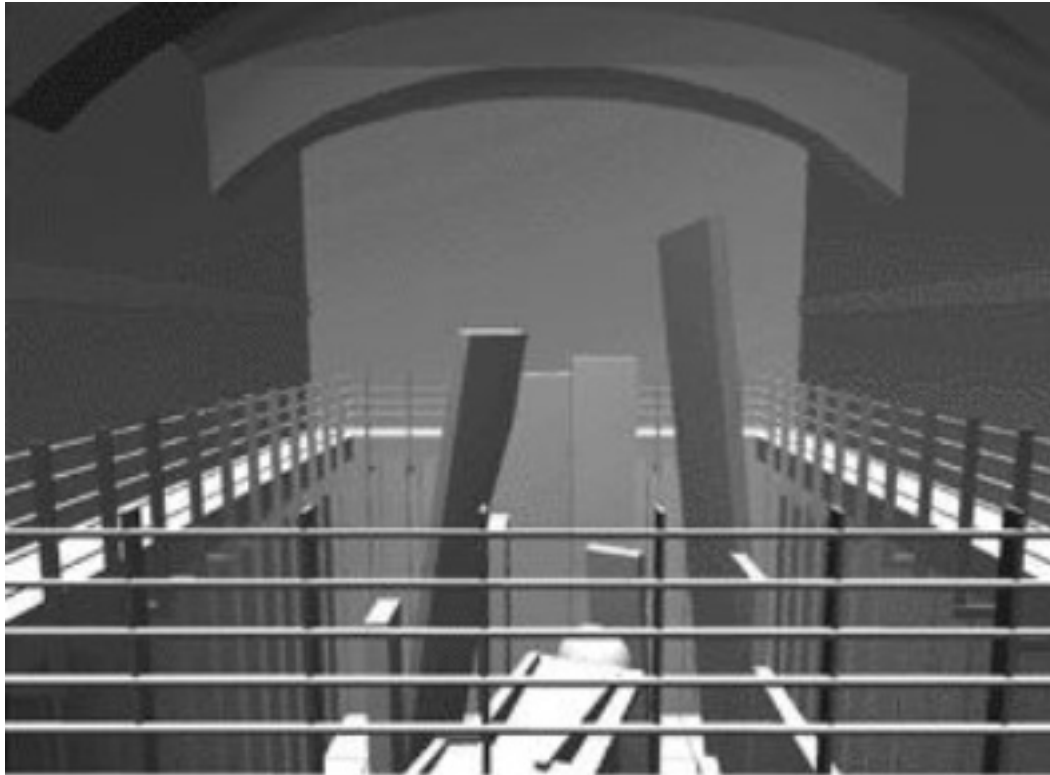

Fig. 1 - 1:1 performance area (digital representation).

Full-scale Lab

Practically every design and planning activity aims at its specific realization in the built reality. Any decisions could and should be made on the basis of original substitutes. The actual dimensions and proportions of space can be grasped in 1:1 scale without any "mental detours". Furthermore, the interaction of light, color and surface can be illustrated best in the 1:1 model. The experience of "space" is a multiple experience involving not only the visual sense, but also all other senses (touching, smelling, hearing and feeling). It is, however, common sense, that the perception of visual events predominates in our culture due to our "one-way conditioning" and cultivation of situations requiring different sensual involvement are grossly neglected. Man and space are always interacting. Spatial perception as such relies on innumerable pieces of information: the three-dimensional architectural-constructional urban space is complex and amounts to more than the mere accumulation of modeled polygons. Integration of spatial dimensions, proportions and properties thus considerably adds to spatial realizations and planning work.

The term "full-scale lab" is made up of the components *full-scale* and *laboratory*. Though complicated to integrate the future environment completely the full-scale representation can illustrate the (inter-) action of light, color and material and surface in architectural space in an optimum manner. Therefore the question arises what full-scale simulation can convey in the course of design work. Is it focussed at making for the independent investigation of architectural space and thus furnishing reasonings for decisions throughout the confrontation with "space"? Or should the one structuring space rather rely on his own imaginative power? Every design activity is finally directed towards its realization in the built environment. Essence and purpose of simulations in full scale is to recognize any shortcomings. The 1:1 model lends itself to the representation of and experimenting with various arrangements.

VR-Kit

Once input of the 3D-computer model in a specific system environment (Dos-PC, Mac, Unix, etc.) has been completed it can be stored by means of a data exchange formated and imported into a *virtual reality kit*. In reproducing the stereoscopic real time representation including the reaction to the constantly changing angle of view and the position of the viewer in Cyberspace becomes possible. The cybernaut thus has the impression of moving in virtual space determining his way through space by his his own actions. If the viewer turns his head to the right - 360 degree movements are possible - the environment picture changes likewise as any of his movements are received by a sensor and processed accordingly. A VR-installation provides of one or more sophisticated graphic computers. Periphery tools such as data gloves, eyephone-

helmets equipped with color-LCDs and head-tracking sensors can be added. Even though several cybernauts can walk simultaneously through the virtual model the motional radius is limited in VR-work. It seems wise to provide certain limitations. The viewer could e.g. have the option of "only" walking across the floor thus sensing gravitation and not viewing the virtual model from the bird`s eye view. Space cutoffs are not experienced as "real" border-lines provided one can walk through a wall. Regarding its limitations in performance representation of e.g. textures by means of texture mapping are somewhat confined.

Fig. 2 Cybernaut in the Capella Speciosa (Image: E. Schmidinger).

VR-Light: Stereo-display

This equipment is also known as *LCD-glasses*.   The screen format of the left and right single frame matches the screen frequency, the left and the right LCD alternating in turning not transparent. The quick change makes for the stereoscopic impression. The sequence is located in front of the screen, the viewer, however, being able to "experience" his model individually by means of mouse movements; depending on the efficiency of hardware also "walk-throughs" can be generated in real time. The affinity to the computer-generated stereo-picture is obvious and connections to *virtual reality* become evident, as adapted stereo-displays are used in the *Eyephone-Helmet* in the VR-kit. Provided the cooperation of hard- and software is optimized in future also in the "low-end-area", various implementations of this application will arise.

Exemplification I - Housing Space in Vienna
Large-scale virtually generated housing space was illustrated by means of video-projections in a building cover specifically designed therefore. Housing projects of the Municipality of Vienna being built at present or being in the planning stage are shown. The four screens are drawn up alongside the sides of a square the projection of real time animations providing a kind of pseudo-panoramic reality. The stereoscopic representation is not considered on account of practical and technical reasons.

Drawing attention to the building forms is achieved efficiently in the illustration, the environment only being globally suggested (with a few trees). People are not shown in this technically perfect presentation, being a basic matter of abstraction of "level of detail". What is remarkable is that the demands of the users are constantly increasing. The installation of a *joystick* in the center of the room like on an altar is to invite to interact. "I am to contribute in determining" the navigating visitor is supposed to think. This representation of the world shows clear analogies to numerous computer games and stresses the "I-perspective". The environment is seen by the eyes of the hero. The possible narrowing down of human perceptions has already been pointed out. What possibilities does VR provide for perceiving an electronically created world not as cold computer graphics, but as a cosy computer-art world. Not only the representation as such, but also the atmosphere conveyed by this representation makes for the full "immersion".

Virtual Reality Modeling Language (VRML)

VRML makes for the interactive exploring of three-dimensional models and individual interfering regarding the source code. The three-dimensional VRML-scene lends itself thus to spatial draft- and planning work and can be composed using e.g. a text editor. Compact files without unnecessary information are issued, complex forms, however, can not be described by means of a "indexed face set". For those finding editing work from scratch too complicated available objects by means of other applications (3D-studio, lightwave 3D, etc.) can be exported. As the converted objects are mostly not developed for real time rendering they normally have to be optimized, i.e. superfluous information is to be eliminated, as the consume computer capacity.

Principally, VRML-implementations aim at dealing with new concepts. Agglomerated structures require that objects can be connected via transformations with one another. The infinity issue calls for great skills concerning navigation: by means of *Anchor* a "new world" can be entered. A single world origin does not exist any longer: local systems of coordinates serve as reference point for so-called Inline-models. A VRML-models are transported into other VRML-models. Two different models interact, the problem of being hard to follow up is coped with by means of modular representations.

Fig. 4 Front page of http://fbra.tuwien.ac.at/ vrml/ (Image: Borislav Petrov).

Exemplification II - Lego: Digital and Analogue

The full-scale lab opened in 1992 at the Vienna University enabled the students to translate their spatial ideas into reality. Not conventional building materials, such as concrete, bricks and plaster are used, but rather a multitude of building elements, such as Mero-rods, Brik-stones, scaffolding poles and the like. Due to the space simulations in full-scale performed hitherto computer-generated space simulations have proved handy as preparation in lab work. The main goal of the recently issued thesis of *Lubomir Kulisev* was the development of a digital building brick system called "Lubolego" on the basis of the present state of appearance of the full-scale lab and the building elements available to be used for computer-assisted space simulations. The ArchiCAD 4.55 (by Graphisoft TM) program was selected for generating and optimizing the 3D-computer model. Those objects making up the set installation of the full-scale lab (working platform, wall girders, etc.) as well as the building elements were generated authentically and stored as individual library elements. Some of these elements were unique parts to be implemented several times in space installations. On completion of input work the Archicad-documents were stored in the so-called *Wavefront-format* and transmitted for viewing purposes to the field computer SGI-Onyx RE II of the Department for Urban and Regional Planning and Architecture at the Vienna University of Technology. This also resulted in the transformation into a VRML-model.

Connection of spatial simulation in full-scale and computer-assisted space simulation was advanced in the course of this work. The advantages of this integration are obviously as follows: in digital space simulation the size proportions of the individual building parts of a spatial arrangement can be efficiently investigated. Drawing-up of a three-dimensional project proceeds at a rate unmatched- provided sufficient CAD-skills - compared to the building of the same project in full-scale. The technical problems occurring by placing in the 1:1 scale can be neglected. The ease of illustrating ideas on the screen might lead to the impression that the real building work of the planned object might be as easily accomplished. Here, however, one is greatly mistaking. The positioning of a 3D-Mero triangular girder only requires a mere mouse click in the groundplan window in comparison to the actual 30-minutes of work of three individuals. The great advantage of a computer simulation surely is that a single person can simulate complicated spatial configurations even on his own, which, on the other hand might also amount to a disadvantage, loosing practically unintentionally the relation to reality, due to his moving in "completely different dimensions". Many possibilities being "feasible" on the screen cannot or only hardly be translated into reality (e.g. suspended ceiling members, etc.)

The practical use of VRML for architecture can be hardly estimated. Principally, there is the possibility of offering a lecture at the Vienna University of Technology "remote", thus making it accessible to students of other departments and universities - such as the Graz University of Technology - this also being in line with the intention of the project. VRML-models occur as by-product as it were of modeling work. What is of great advantage is that it is a language not being platform-bound. VRML is not restricted to transmitting three-dimensional geometric information, but also makes for the implementation of various characteristics (e.g. collision protection), i.e. a vast range of perceptive possibilities of space. The independent navigation in real time calls for the investigation of a spatial situation. Adequate viewing possibilities, however, are presently only provided by high-speed computers.
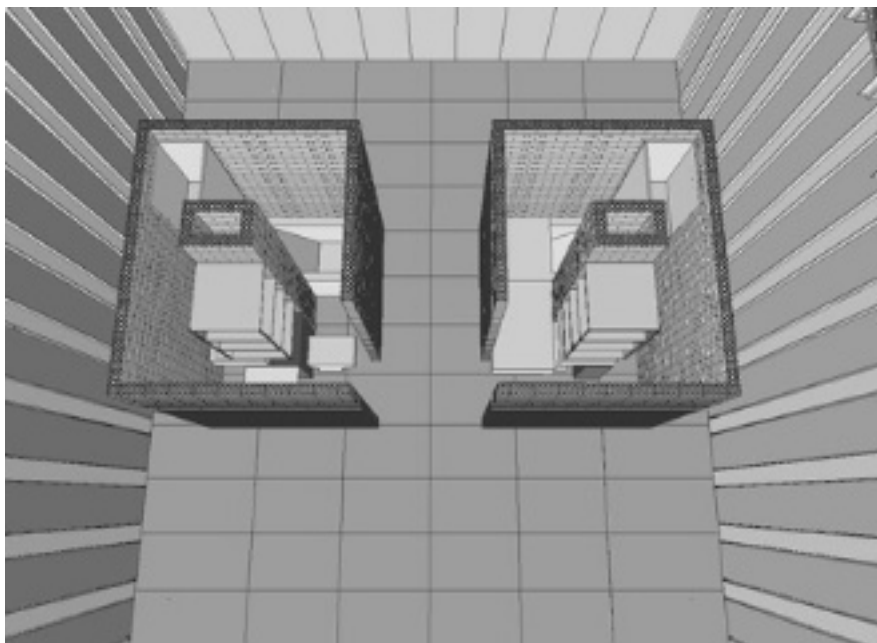
Fig. 6 Practical work with Lubolego (Image: L. Kulisev).

Upshot

To which extent is this of interest for the architect`s office? In this context two essential working steps are to be differentiated. First of all, modeling work can be performed on any available platform. Regarding a number of tasks the demands as to computer performance are not too great in this phase. A model can also be split up into part models. Secondly, an adequate compu-ter performance is required depending on the extent and complexity of data to be represented, especially in real time representations. VR thus offers an additional viewing possibility of an already generated 3D-model in architec-tural production without having to build an extravagant physical model using additional materials.
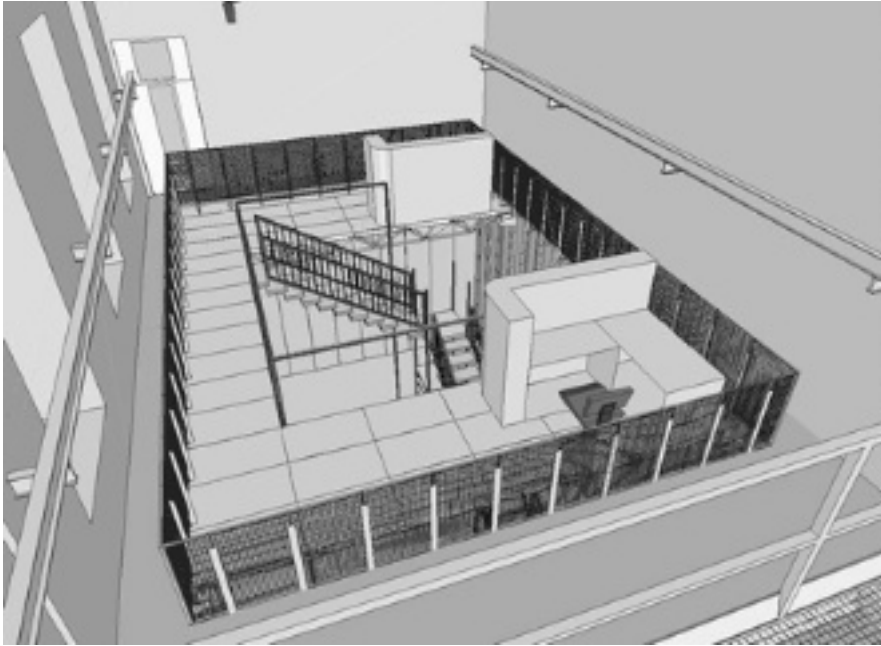
Fig. 7 Vienna Full-scale Lab with Lubolego (L. Kulisev).

The required VR-equipment must not be available at the working site, but can be purchased on demand as available service. The problem of conversion is to be treated individually within these considerations. Practically all architect's programs provide of more than a single DXF-interface. It is to be pointed out that this interface though pretty popular does not always work faultlessly and may require akward re-editing afterwards. Thorough and careful preparation in the modeling phase is a must saving unnecessary re-processing and annoyance. Accordingly, trial runs will prove wise in between. More and more projects are being subjected to CAD three-dimensional modeling featuring differing degrees of detailing. Last, but not least, a pragmatic argument in favor of VR is to be mentioned. VR-models are not only "en vogue", but also are to be regarded as "ecologically compatible", as they are not built.

The unfavorable economic relation regarding effort and benefit often is one of the reasons why (complete) physical 1:1 models are only rarely built. Therefore, representation by means of the less costly virtual models are strongly preferred, also because they can be used simultaneously at many locations due to their digital nature (no loss of information when duplicated). It lends itself particularly well to spatial planning and design work regarding the fields of urban development planning and urban and regional planning. A well-balanced combination of physical and virtual (existing and planned) models in full scale accounting for the field- and problem type, the degree of detailing and scale might gain in importance in the future ("Real Realities - Virtual Realities" (R.R.-V.R). Generating visions and utopias ("Virtual Virtualities V.V.) may also contribute to spatial development and design.

Is Architecture Going to Reconcile Basic Values?
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Introduction
The title "Real Reality" provokes immediate reactions. There is more than one reality. Therefore we have to talk about realities and we will confront you with a few, but important, aspects which influence our work, both as architects and as teachers.

The built environment all over Europe is the result of an enormous growth in the last 50 years. During this period, in Switzerland around 65 % of our building were produced. In countries, which were devastated by World-War-II the percentage must be even higher.

We have to accept as one reality of our profession that:

- in future we will mainly build within zones, which have already been constructed;
- we will not design "new-towns" in the wider agglomeration, but make additions between buildings and complete the existing build-fabric.

Therefore, we will be confronted with two quite different urban fabrics: the traditional towns with mainly continuous masses and the pattern of isolated blocks within a continuous space, the approach of this century. To both of these existing fabrics we have to find adequate architectural answers (fig. 1-2).

How to Characterize the Actual Tendencies ?
There are tendencies in actual approaches, which cannot be considered as models for future developments:

- There is a strong appreciation of the pure volume. The building acts as a crystal, selfish, detached, isolated with very little relations to the immediate and wider environment;
- The façade is treated like an image containing a message. The façade of the parking building of Stanley Tigerman in Downtown Chicago imitates the front part of a luxury car. The entrance to the public elevators are placed under the tires. It is a egocentric façade which totally neglects the existing façades of the street;
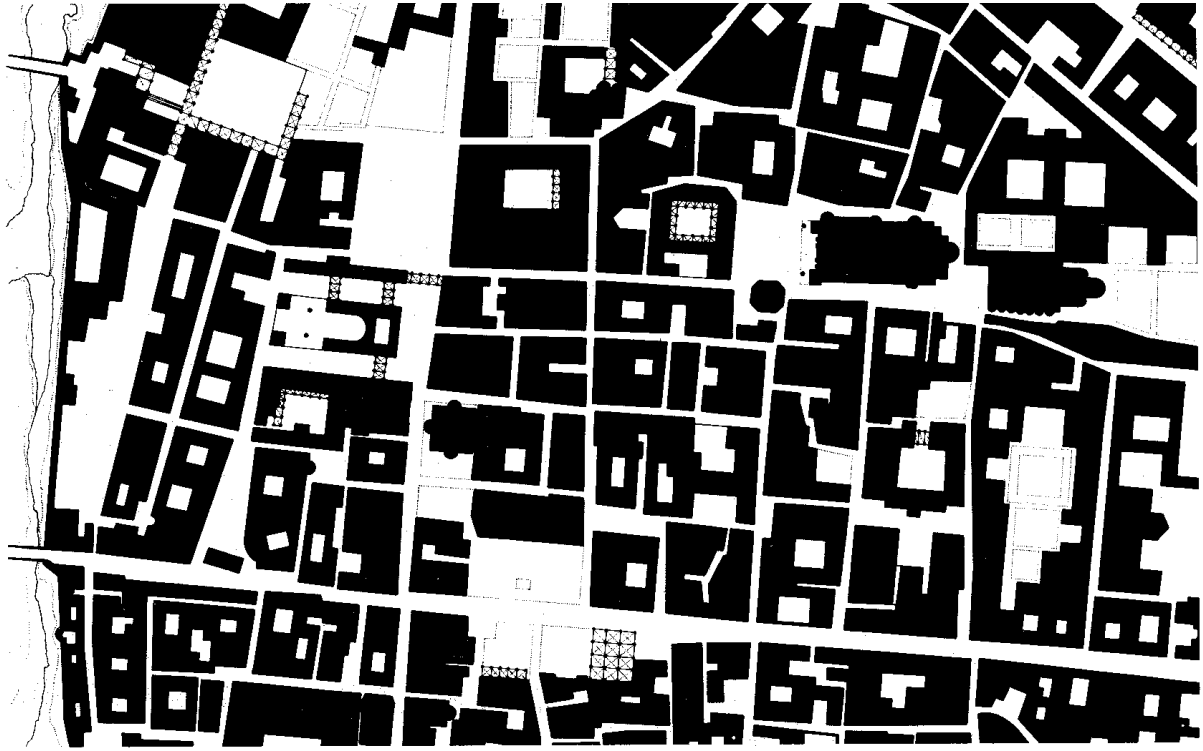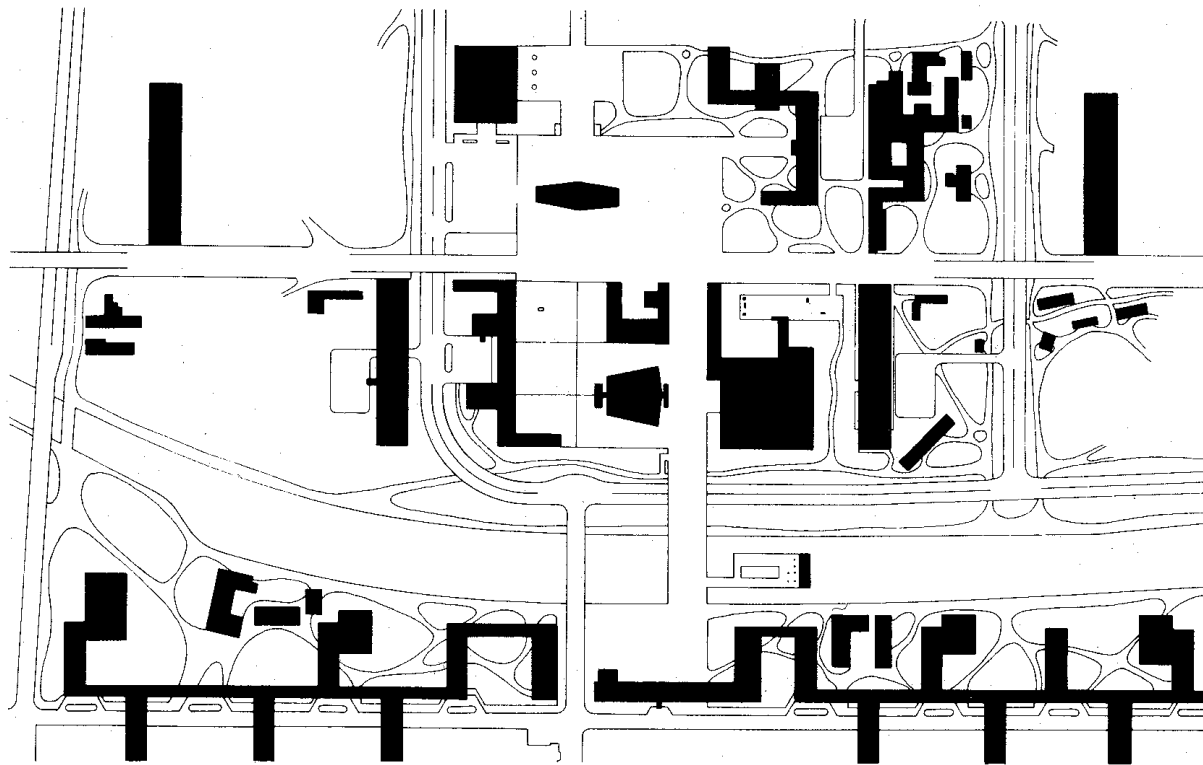
Fig. 1 City Plan of Parma (Italy).

Fig. 2 Le Corbusier: Project for St. Dié (Both plans are at the same scale).

- The signal box of the Swiss railway in Basel of *Herzog and De Meuron* is surrounded by railway tracks. It is quite evident that it acts as a free-standing solitaire. The concrete shell is wrapped with 20 cm wide copper strips. The copper-facing suggest to express an effect similar to that of a Faraday cage, an effect which is already guaranteed by the concrete shell. At certain places the strips are twisted in order to admit daylight to enter the rooms. The symbolic expression is more important than the comfort of the people, who might sometimes have the desire to look out of the windows into the nearer and wider surroundings.

The main concern of these examples is the message. According to this approach, the façade has to convey something; it has to give us some information. The façade (even the building and finally architecture itself) becomes a medium. We live today in a world of media. Each medium tries to compete with the others, to be more attractive, to dominate its surroundings, to be more astonishing, more surprising than the others. A building conceived as media has to be fully competitive and to keep this attractiveness in an ever-changing world. How can that be realized? This might be an actual but not an accurate question to architecture. It doesn't bring you closer to an understanding of architectural qualities.

Architecture Has to Give Space to Basic Values of Human Life

The role of architecture in an ever-changing world is not to act as an advertising media. The world of substitutes, the world of artificial and virtual environment will strengthen the desire and the necessity of real and practical experiences. In our media-saturated times it depends amongst others on architecture, if humankind is exposed to the direct aesthetic, sensitive and sensible experience of the "real". We count upon our built environment to form the stable matrix of our life. It has to protect us, to stand up to us, to give us places to be at home, to mould our native land. Buildings and all architectural interventions are what one might call "primary objects". They are necessarily permanent, largely impassive, sustainable and real.

To create one's own space and to define a specific place of its own, a place to be and to feel good, belongs to basic human needs. Life takes place in space. The quality of the spatial environment affects the human well-being. Architecture has to give space to basic human values.

Why Basic Spatial Qualities Are so often Underestimated?

It is very difficult to talk about spatial qualities. In architectural history and theory there are a lot of treatises about form, construction, use, composition,

Fig. 3a-b.

etc., but only few about architectural space. There are important epochs in the history of architecture, where the term *space* was not used, even in cases when the buildings of the epoch were spatially of excellent quality. It is furthermore very difficult to teach spatial qualities. There are teachers (and even good and committed ones) which consider this matter as too difficult to be treated in a school of architecture and avoid it. There is very little concrete and formalised didactic experience about architectural space.
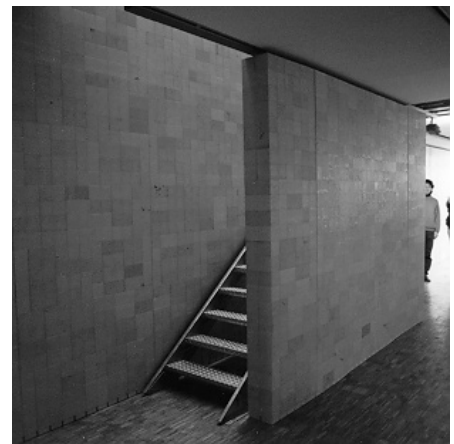
Fig. 4a-c.

Fig. 5a-b

Fig. 6a-b.

The Chances and the Responsibilities of a Full-scale Laboratory

The 1:1 abstractions in a full-scale laboratory makes specific aspects of spatial qualities evident. Spatial qualities can be experienced and treated. The full-scale model is an abstraction. In that quality it represents certain aspects of reality. It is selective and in being so, makes elementary aspects of spatial qualities visible and therefore teachable. The constructions are sensible as real spaces with real dimensions, real surfaces and real forms of a shaped void. The relation between the masses and the void can be changed. The differences of spatial qualities can be experienced and be related to the physical alterations of the massive elements. Space-defining elements can be placed whatsoever or in an sensitive order. The necessity of nearness and proximity can be felt, also changes in dimension and form. Openings between several spaces affects again the spatial recognition. To walk in space means also to go up stairs. To move upward and downward is spatially not the same movement. The spatial verticality can be stressed by continuous walls, by double-height spaces, by balustrades, etc. (fig. 3 to 11).

The full-scale model is one tool among others. Each tool has its limitations and its advantages. There is no complete tool. Every-one is selective and reveals particular aspects of the imagined building. It is evident, that each tool is also an obstacle. No tool can overcome totally the gap between real building and the representation. Every tool is also a trap. It suggests to develop the project in a certain way. We have therefore come to the conclusion, that all projects should be developed by means of different tools, which, preferably, should be complementary in their effect.

Taking into account the difficulties of discussing and of teaching spatial qualities, we have to welcome every tool which leads to a better understanding of these properties. This even more so, when the students can make their experiences on their-own and acquire a personal capacity to imagine architectural space, as it is the case in a full-scale laboratory.

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Light as Language

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Light of shades
Light of purple shadows
Light of green in early spring
Light which sings of hope -
for millions of years singing

Introduction

Our first source of light was flames from the fire. This was and still is a warm central light which invites us to sit down. The hearth remains a place to rest and feel peace. We also experience the inviting effect related to stairs where the impact of light is continuing the upward movement. And we experience the language of light announcing an entrance as indicated by this photo from the laboratory.

Fig. 1 The exhibition exercise.

A beautiful example is the entrance to Francisco Gilardi House by *Luis Barragan* where light is filtered through yellow glass. This particular entrance is vividly described in Sailo's monography about the Mexican architect [1]:

> "Opening the front door and proceeding down a dark corridor deep into the house, one is suddenly showered by golden light. More than a corridor this area seems like a time tunnel that provides a baptism of light as it leads one into a different dimension."

The architectural space of Luis Barragan is often described with the expression "emotional architecture".

Stained glass has mostly been used in churches. Daylight became coloured in an attempt to enrich the ceremonies creating an illusion of a better world in heaven. More than any other type of room the churchroom has been worked with in order to obtain an atmosphere. In the church at *Björkhagen* outside Stockholm light is let in through relatively small square openings. Contrasting height the openings give an intimacy, and we experience the thick wall as a protection between the inner and outer world. Related to form and dimension light is clearly perceived as a means to manifest the smallness of scale in the large space. The architect, Sigurd Lewerenz wanted to limit the effect of light to a minimum which today is destroyed by the spots directed on the altar wall. Too clearly the dimension of height is defined by the high light level. It was supposed to end in darkness. Using spots in this way is a total lack of respect for the architect's intention. The greater was my joy coming to Adolf Loos' Kärntner Bar where restoration work has been done in a most respectful way. The intimate enclosure is opened by mirrors in the upper part of the walls where light is discretely suffusing the subtle play of materials. No reflections spoil the illusionistic effect of the mirrors except from the twinkling light in glasses and shelves of glass.

The language of light may be silent. It may be violent. At discotheques light is shouting at us. The coloured spots sway all over the place enhancing the level of music to help bring people into another state of consciousness. Today when the general level of light is higher than ever before it is interesting to learn the research which has been done in Boston this spring. Research results at Boston University testify that a constant high level of light causes malfunction in the gland releasing melatonin which regulates our sleep. With the constant stimulus of strong light the subtle body is not given any message to slow down. We can't expect modern man to live in the regular rhythm of going to bed when it is dark and rising with the dawn. But we may learn to regulate the light level, slowly lowering the level some time before going to sleep.

Fig. 2 Kärntner Bar (A. Loos - Vienna).
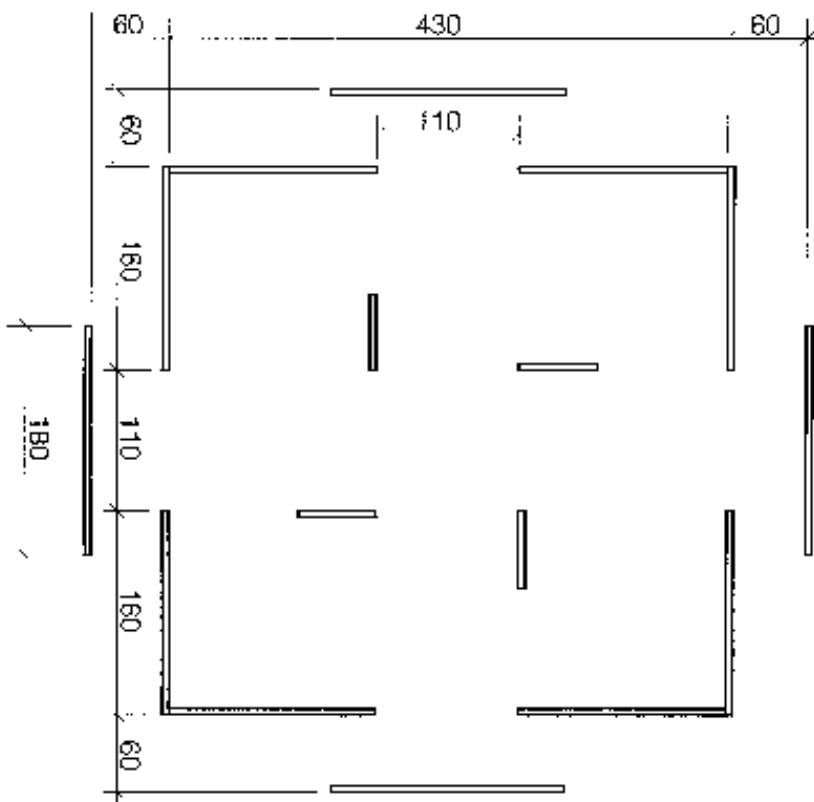
Fig. 3 Groundfloorplan of an exercise.

Exercise: Interplay of Light and Form

The purpose of the exercise is to demonstrate how light can alter the appearant form of a room. The wall elements are placed in an open order allowing to emphasize different spacial configurations by the light setting:

A. The square form

B. The cross form

C. The rectangular form

D. Total disorder
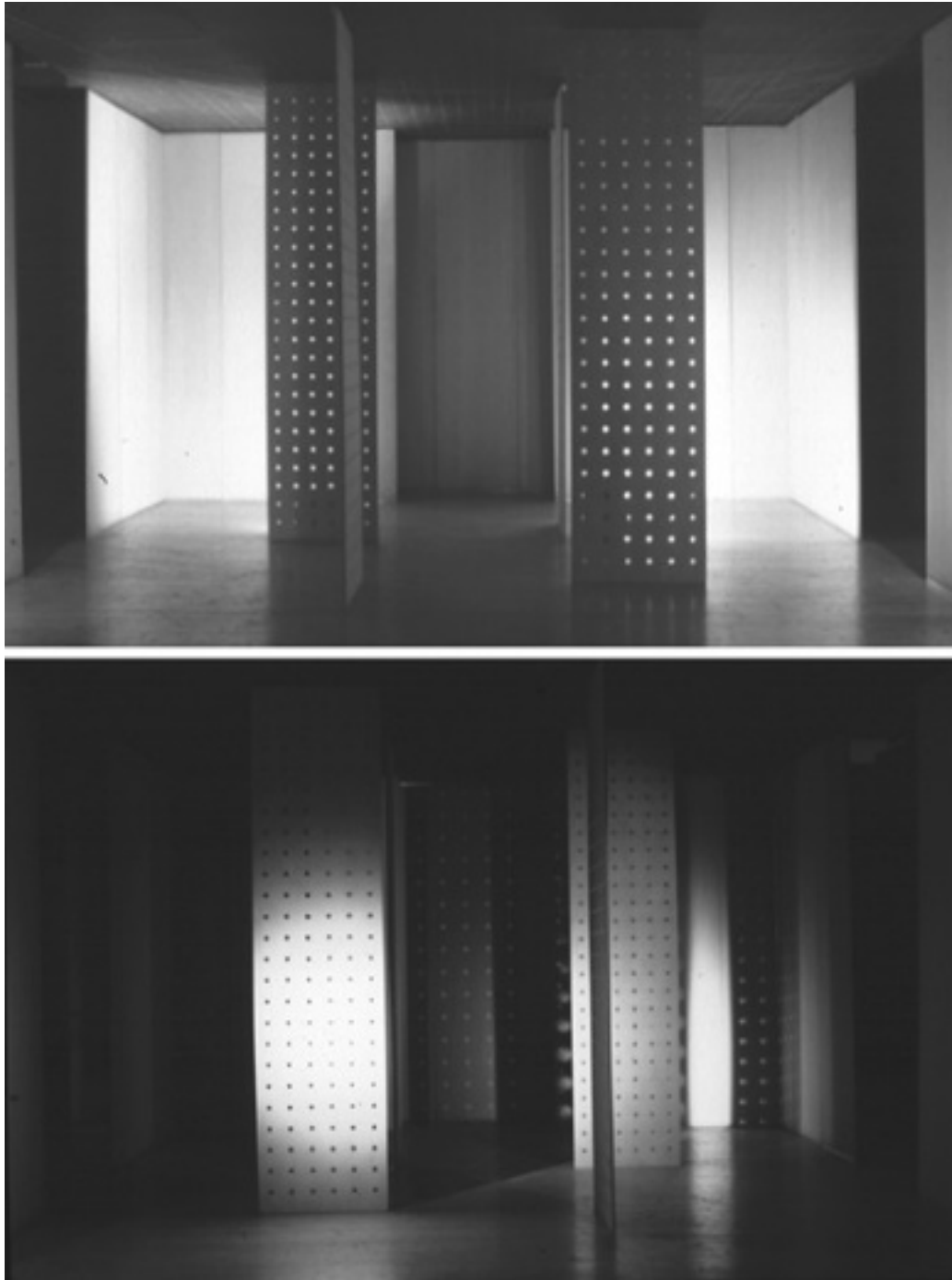
Fig. 4a-b (square form resp. total disorder).

Case Study: A Doctor's Waitingroom

Spaces without access to daylight have been of special interest in our experimental work [2]. Let us start by asking: What do we have in common when we are waiting to come in to a doctor? We are nervous and we sometimes feel miserable. Analyzing the situation we understand the need for an interior that takes our state of mind or may I say, our soul into consideration. The level of light is important in this situation. Light has to speak softly. Instead of the ordinary strong light in the middle of the ceiling, several spots are selected to light the small tables separating the seats. The separation is supposed to give a feeling of privacy. By the low row of reflected planes we experience an intimate and warming atmosphere in the room. A special place for children contributes to the total impression of calm. As the space is considered to be without daylight a recess is built in the wall (depth 50 cm from the outer wall). Light from spots behind the wall elements on each side passes through the steel construction creating a play of shadows on the walls. We perceive an openess which is "breathing" in the space, most favourable when all seats are occupied.

Fig. 5 A steel construction may be used to enlarge an existing window.

Conclusions

The language of light is visual defining form‑space relationships, and it is an emotional language moving our inner selves. Both factors are essential to bear in mind lighting architectural spaces. With regard to a definition of form we experience the damage of spots daily. Constructive elements like cloumns and beams are visually dissolved or cut into pieces. The spotlight is a strong means which must be used carefully without distorting the perceptual clarity. Light is a dominant quality in creating character and mood of a room. Shadow is another quality enhancing the impression of light. Light and dark, we need the darkness of shadow making effects of contrasts and variations, and also of direction. The effect of directed light is impressive. We obtain a range of lighted spaces in space which may suit a neutral impact of indirect light. A light setting of indirect light alone is not advisable. Being in a forest we experience the principles of articulation. Nature is our best teacher.

References

[1]   Sailo, Yudaka. *Luis Barragan*. Tokyo, 1992.
[2]   An article about corridors was published in International Lighting Review (1989) vol. 2 [see also http://WWW.mogul.no/comein]. This summer another neglected area has been in focus: A doctor's waiting-room.

Experimental Spatial Structures

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Introduction

To speak about *Experimental Spatial Structures* at first means to find the right definition. Therefore we have to find definitions for three different subjects *experiment*, *space* and *structure*.

Experiment - that means to perform scientific experiments. The attempt, the test, the simulation, the model. To do experimental work, that means to take measurements, to count, to compare, to try analyzing, to find out differences between substances. In our case, the experimental character of our work is impressed on working by using different methods to show the basic idea of our theme. To act and to use the full-scale-models with your body. *Space* - that means architectural space which is defined through architectural spatial elements: wall, ceiling, floor, corner, staircase, way, opening, border, edge and so on. So to speak the substances we need to do our experiments. *Structure* - means order. The contemplation and the comparison of different spatial structures allows the division of different basic subjects like: euclidian structures or physical structures or the depth of space and so on. To analyze or to design architectural space by using spatial structures as one possibility to do architectural work. As a summary: the experiment or the attempt to show architectural, spatial structures. Space and spatial structures are not only impressed by forms but also and as a main thing by action and moving in space. The role of full-scale modeling, of experimental work related to "reality" in architecture is to simulate basic situations which are not dependent on ideas how they are developed in particular. We try to give some instructions or impressions of elementary architectural structures which can be used as instruments to design space of life.

History

More than 15 years ago, Prof.Dr. Wolfgang Meisenheimer instigated the "Raumlabor" in Düsseldorf as part of his lessons about basic-theory in architecture. So the possibility arose to work on architecture themes in full-scale-models. The starting point of experiences in space or experiences in architecture. Günter Roth, a sculptor, was responsible for the experiments with figures for several years and he influenced our work in his way to speak about the human body. At present he is working as sculptor in Milano but his message still exists in our room. For more than six years now, the author has been
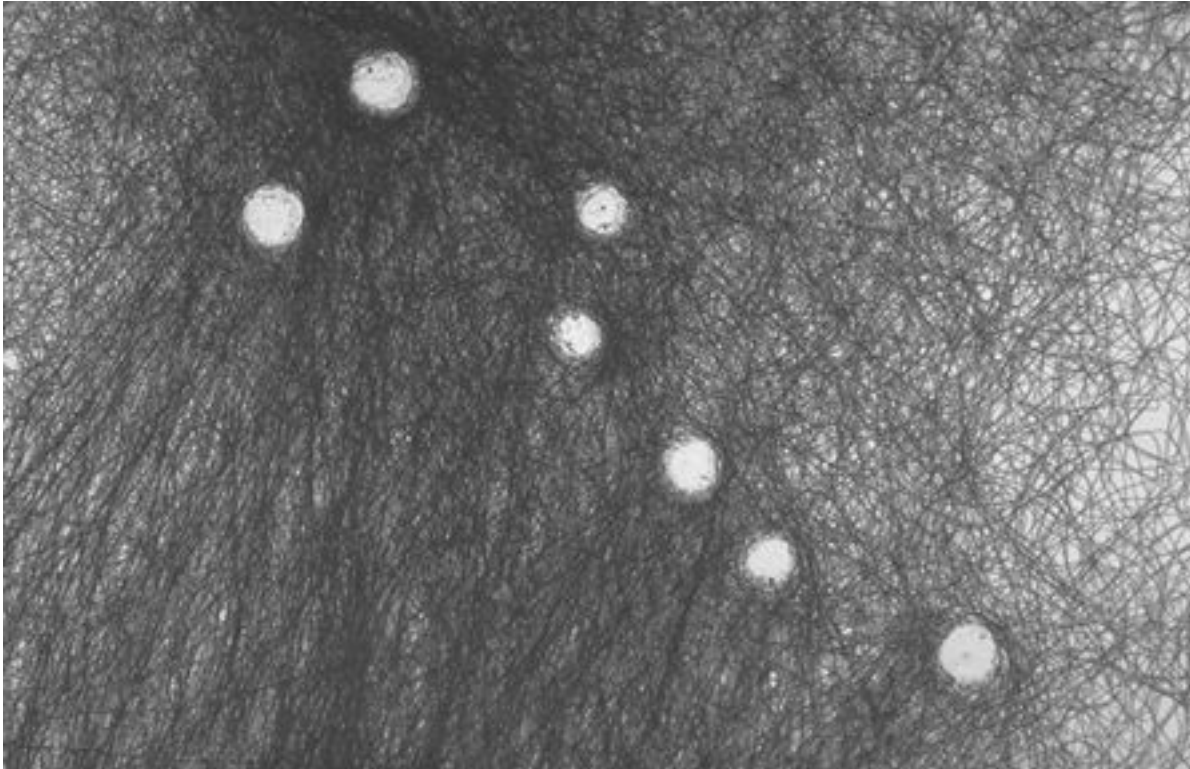
Fig. 1 The way of the ants (documentation of an experiment with ants). It was done by the artist Katharina Meldner. Paths taken by ants are shown, attracted by sugar. They leave behind trails on the sheet of paper spread out in front of their nest. The lines drawn indicate the density of the paths.

working together with Wolfgang Meisenheimer as well as in his main profession as architect. In my opinion the idea of our full-scale work is to ask and to show what architecture is. To give a basic idea of the Düsseldorf full-scale work two examples were chosen as "heading-pictures" (Fig. 1-2).

At first we think about the questions to be explained. Then you have to plan how to get results, how to document your work. The sugar, the paths, the density of paths and why the ants use the paths in this way. If the experiment is successful you know something about the life of ants or, what is better, you find out how to get new questions. Then sometimes it is like a wonderful flower that blooms by showing you the most expressing colors you didn't expect when you saw the bud. We understand the idea of our "Raumlabor" as chance to act architectural ideas where you can work on a stage to show and to see what architecture is. The students are working as inventors, craftsmen, actors, photographers, sculptors, painters, etc. They have to count, to take measurements, to search for new questions, to try answers, to work and design with their whole bodies. To think about the actual carrying out of a "header into the piano" also represents an important part of our studies and experiments: How to build it, where to get the materials, how to design it, how to show it, etc.
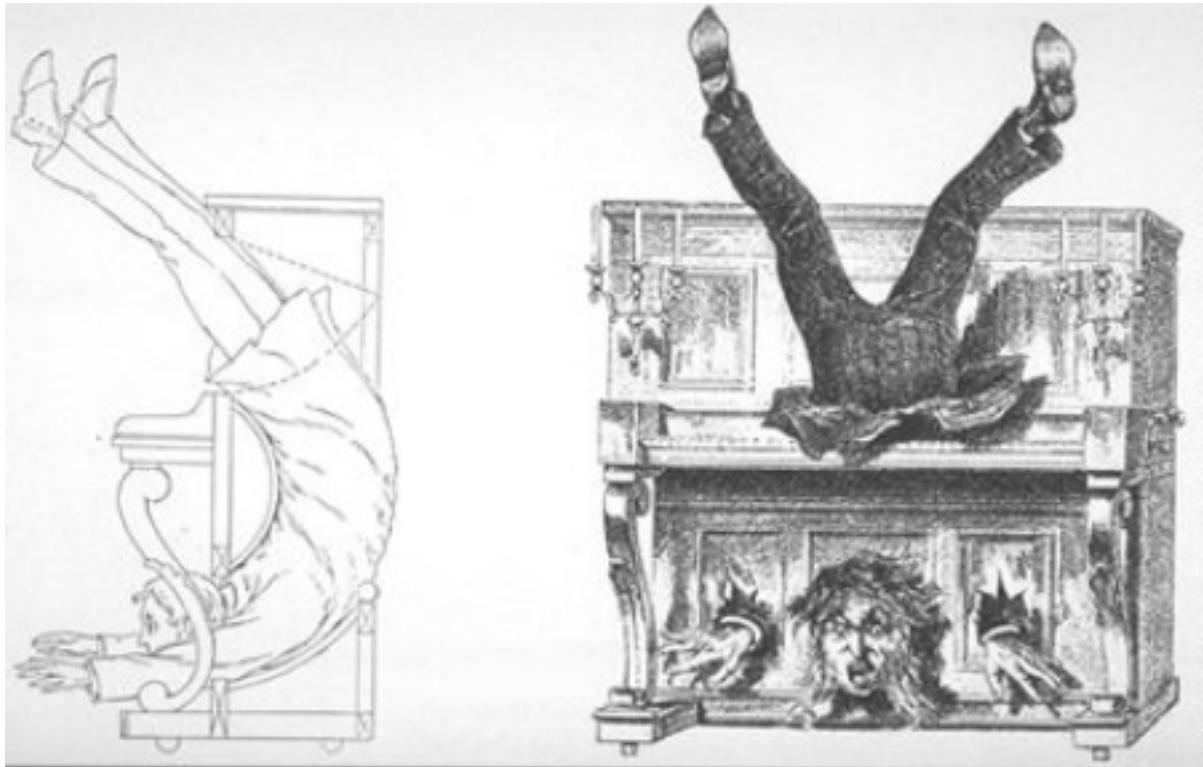
Fig. 2 The header into the piano. This is a drawing done for a theatrical effect. It's a header into the piano and was made in the beginning of this century. To explain it: The casing is empty. The lid above the keyboard is pushed back. The one below is in three places made of rubber-foil which can easily be perforated by head and arms.

The following chapters will give you some information about the establishment of the "Raumlabor Düsseldorf" and you will see some examples of our studies.

Establishment

The dimensions of our experimental area are 10 by 13 meters with a height of 3,60 meters. In this area we divided a field of 9 by 9 meters with canvas-walls in order to get a "white area" where we are able to perform the experiments without disturbing furnitures or materials which are needed to build full-scale-models. We are working with wood, canvas, sand, cord, plaster, concrete, paint, corrugated paper, wire and other materials. Sometimes also old brown leaves, fresh smelling straw, light and fog are used as well as our hifi-installation which allows us to invite exotic birds into our experimental area. Finally, we work with cameras and video and we also have a little DAT-recorder to get some special noises like sounds of the city. Next to the lab there is a little courtyard which is also component of our experiments and which is used as exhibition-gallery for some sculptures.

Organization

In every course about 10 to 15 students participate, coming together once a week for the period of one academic term. We discuss the theme and try to simulate some basic situations by acting with our bodies. Everyone has to do sketches. An important aspect while doing this is, how to show what you have seen and to record the statement of each scene. This work will be continued during the following lessons and after all we produce a documentational booklet. Beneath the full-scale-modelling we also translate several ideas by working with little sculptures, reliefs, models, videos and other methods. In between we discuss the results, ask whether they are useful, and together with guests from other courses we try to get a more colourful and rich documentation. The end of our work is a festival and an exhibition of all we did and every time this is not a mere documentation of our work but also of the fun we had when we made our experiments.

The Human Body

The starting-point of our experiments is to work with your own body. At the same time it is the beginning of full-scale-working. To take measurements and draw with charcoal on big sheets of paper. "Full-scale-drawing...". To compare measurements, to learn something about proportions. To stand or to sit together, in a circle, in a line, in different formations, to show architectural space in a very simple way. To translate movements of figures into abstract forms or to act with no other resources than your body.

Space

To design and to use space. We ask why it has to be formed in this way and try to find out which spatial elements we need to find exact definitions for our subjects and for the results of our experiments. For this chapter full-scale-models which are documented by doing photographs, sketches, videos, etc. have to be build.

Themes

Each semester has a basic-theme as a heading to our work and discussion. There are subjects like: the staircase, the corner, the senses, the labyrinth, the depth of space, architectural motives, light and space and so on. Each theme has also a basic-idea which says something about the meaning of the work that has to be done. Then we have to formulate questions and to ask about what we want to find out and to plan the experiments we have to do. Beneath our practical work, we try to find several examples from the history of architecture to complete the documentation.

Figures 3 and 4a-h are presenting full-scale work showing: Figures and space; Movement in space; The entrance; Impossibilities; The staircase; Staircase-sculptures; The corner; The labyrinth; The depth of space; Ballhaus: exhibition and experiments outside of the "Raumlabor".

Fig. 4a-h.

Experimental Spatial Structures

Together with students from Vienna and Düsseldorf in May 1996 a common course on the theme *Experimental Spatial Structures* was performed for six days at the Viennese Full-scale Lab. The idea was to work out five different structures of space:

a. *Euclidian structures of space* (fig. 5):

- straight line structures, rectangular structures, parallel structures.

b. *Physical structures of space* (fig. 6):

- up and down structures
- the heaviness of mass
- the plumb-line
- the pendulum
- the hammock
- the feet
- the head
- the falling
- etc.

c. *Psycho-physiological structures of space* (fig. 7-8):

- space of living, loving, dying, working space, space to relax in;
- the theatre with 4 old ladies, the welcome, the meal, the amusement in the garden, the singing birds, the light in the evening, falling fog, etc.

d. *The depth of visual space* (fig. 9):

- line of vision
- point of vision
- field of vision
- grading of pieces of scenery which have the same height
- contrasts in colour
- to become narrower
- to become thinner
- etc.

e. *Remember different kinds of spatial structures* (fig. 10)

- for example a building in Vienna and to look for the spatial structures;
- to document the different structures in sketches.

Fig. 5.
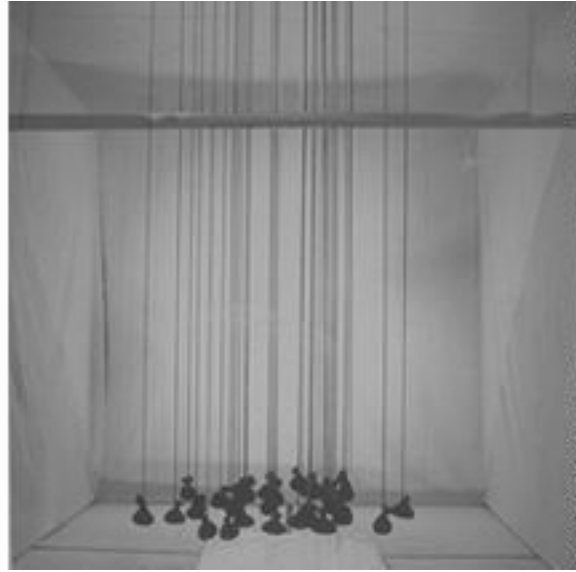
Fig. 6.

Fig. 7a-b.

The 6th day was reserved for the exhibition. While doing some experiment to the different points we wanted to point out their essential marks and the differences between their effects in architecture. The experiments, the discussions and the documentation of different structures which are part of each architecture. The difference between the ways to analyse, to design or to invent architecture.
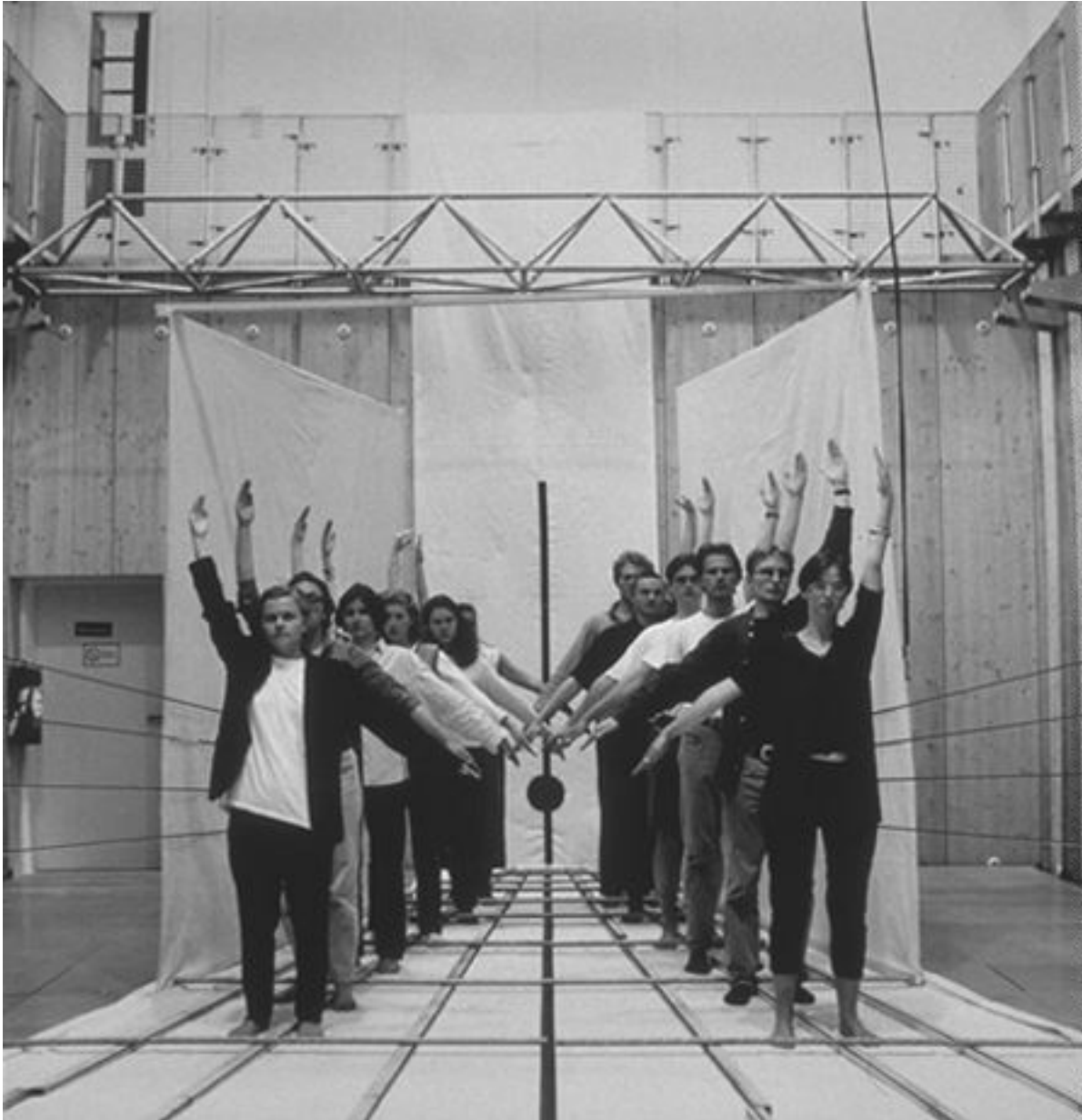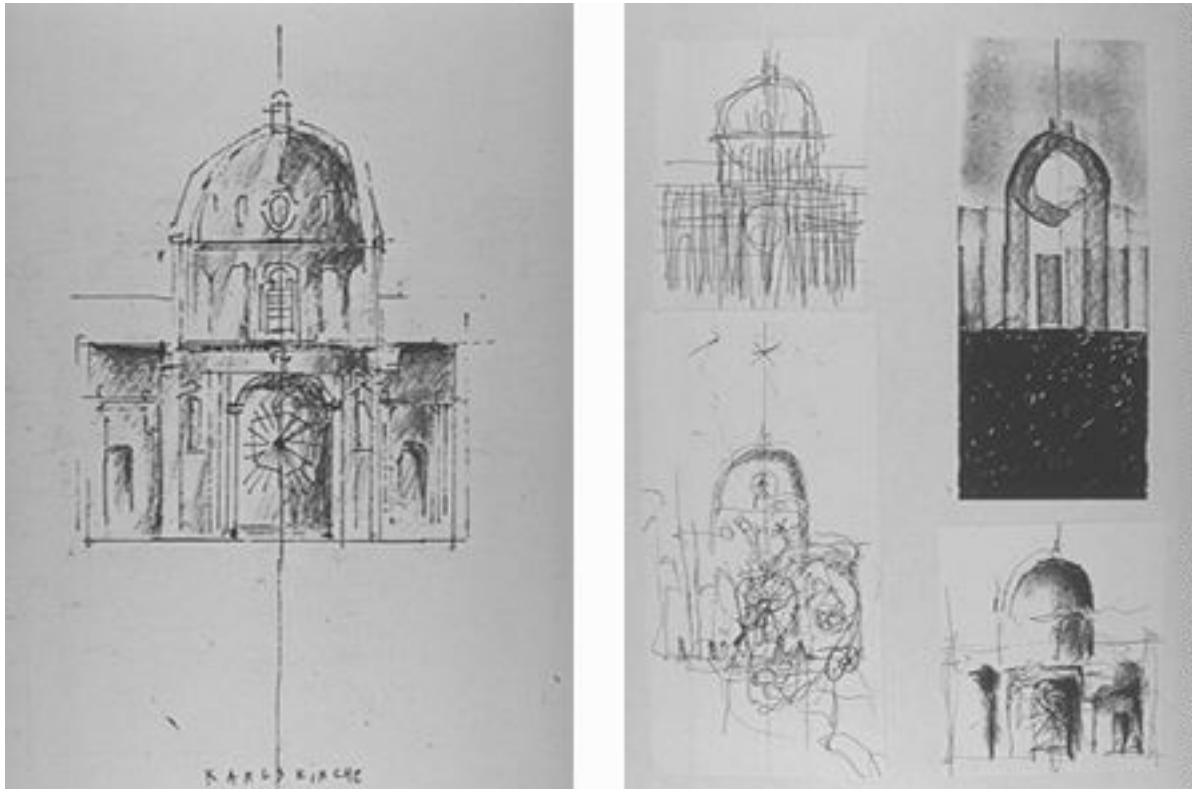
Fig. 8.

Fig. 9a-b.

Fig. 10.

On Truth in True Size

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Ignoring all the discussion whether architecture is art or rather natural science, whether its socio-political task is more important than fulfilment of its purpose, whether ... etc., etc. Beside this I would like to reduce all attempts of definition to the simplest common denominator: Architecture is - unless it wants to be merely conceptual art - three-dimensional and material. Architecture can only fulfil its purpose, can only bear burdens as well as aesthetic contents when all the ideas, upon which it is based, are put into practice, i.e. materialized. This materialization is preceeded by a lengthy process: planning. Basically, planning is simply the anticipation of future architectural reality, it formulates instructions, it is the prognosis of a desirable quality (to be striven for). Planning could also be called a prophecy. The statement that something will be or have to be a certain way does not mean that it will also be right that way. The prophet, in our case the architect, might well be wrong, as it is often enough the case. Our environment is disfigured with buildings that might have been well meant but in fact were major mistakes; they are constructed errors, since this very conclusion is often only made when the structure is finished.

Findings that could be drawn from that are hardly transferable to the future, since architecture is prototypical, it is always created anew, it is always a large-scale experiment, the result of which will only be foreseeable after the prototype has been built. Only then does the truth become apparent. For truth is the reflection of reality. But truth is also the assertion of statements on circumstances or things in relation to the congruence of statement and thing. The reality on the other hand is the world of objects and conditions, of things (already) existing independent of wishes and ideas. So how is an architect supposed to find the truth in his planning, when what he is planning (with all the connected expectations) and what he is actually building cannot be examined as to its coherence?

Considering architecture as an investment good and its immense costs, the endeavour to find out the truth about a building long before the topping-out ceremony or the commissioning of a building is understandable. So we simulate it. Drawings that are usually made, models that are built, perspectives, computer animations, pages of descriptive texts are attempts to simulate future reality. They are the reflection of a desired, not an existing, reality; there is no truth attached to them a priori.

There are more and more refined, sophisticated and expressive simulation techniques, they are coming to resemble reality more and more but they cannot yet replace it. What remains is the simulation of reality by reality, by the full-scale model.

Let us now transfer this problem to the training of architects. In addition to the standards of achievement which are usually sought for, universities and other architectural schools should aim at teaching people how to make all the decisions necessary for creating an architectural reality. Decisions in the field of design, construction, function, construction physics, psychology, economy, aesthetics, etc. At universities students are supposed to learn how to make architecture, in reality they only learn to plan architecture. Used to learning about architecture from glossy magazines (it's only the international level that counts), where shift-lens corrected photos and ground plans and sections that are hardly legible because they are conceived as graphics are passed off as reality, students embark on the same road when they create architecture: the way of conception determines the way of reproduction. They learn how to draw sectional drawings that no one will ever see, to build models without interior rooms, to make drawings that develop an artistic life of their own as graphics (where they even might be justified), but are no closer to truth than a literary description of the same object.

We are penetrating deeper and deeper into art the task of which is not to reflect the existing visible but to make new things visible. Art as a medium of recording reality ceased to exist long ago. I know very well that contact with art is the source from which architecture gains its power, and I am well aware that no architect can do without the aforementioned instruments of presentation and simulation, so I do not oppose these facts, but the exclusivity of their occurrence, I oppose the conception that there is no need for looking for alternatives which could take us nearer to the truth. However, there is one alternative, it is working in true size.

So what I am doing at my University, is to show the students how to design, construct and how to build architectural things. Constructing alone would mean restriction to the craft, planning alone is the method of approaching the phenomenon of building as it is usually done at architectural schools. I start out from the fact that building is the creation of architecture, and that this is a process which is not finished with the determination of aesthetic qualities, it rather begins there. Therefore I offer my students what will become their proper and most important task as future architects, namely planning and building and thus proving that the considerations, decisions, instructions and design formulations were right.

Fig. 1 Emergency shelter, setting up time 1 minute (The truth about time).
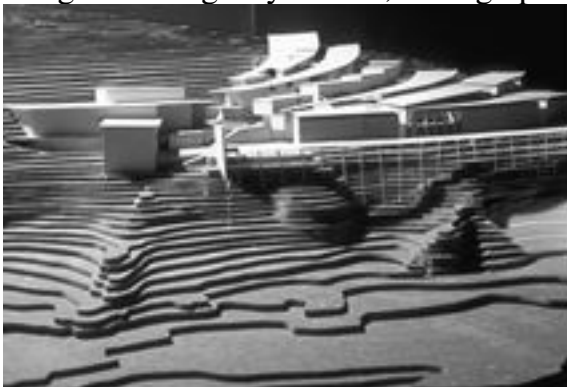
Fig. 2a-b Amphitheater in Crete (The truth about the dialogue with landscape).

The prototype becomes constructed reality, an evaluation instrument, unmistakable proof of truth (of course there are numerous other goals of teaching that can be striven for and achieved by working in real contexts. The connections between material, construction and form, the expansion of product-oriented thinking by process-oriented thinking, the understanding by touching and much more - but this is not our topic here today).

In practical life the idea of true size building as a method of simulation has its limits, of course: dimensions speak against scale and costs against logic. Nobody would seriously contemplate building a hospital, an administrative building or an airport on a 1:1 scale just for the sake of truth; a hospital room, an

office unit or a cluster of check-in desks anytime. A lot was simulated on the computer for Norman Foster's high-rise building in Frankfurt which embarks on new roads of intelligent construction, but a complete three-storey section, including the very sophisticated facade, was still built, as a prototype, as a field of experiment, as a proof of truth. The same applies to studies. As I've mentioned before, I am against any type of exclusivity, also in this case. It would be stupid to base architectural studies on the examination of reality. But at least once during their studies, all students should be offered the possibility to experience the metamorphosis of their ideas into real reality and to draw their experience from the antagonism that materialization opposes to imagination. It is not so important whether the reality is restricted to a chair or refers to a house. In the spirit of exemplary learning, which is based on the understanding that it is no longer possible to learn everything, but only the principal, the exemplary and the typical, I advocate that handling true size should be tried once and that the experience can be transferred to other situations.

In true size a rectangle with a broken line becomes a room with an opening, two crossed lines become a wooden joint, a zone with dotted symbols becomes a concrete element where formwork must be erected and dismantled, etc. A model turns into tangible space that should not only fulfil its purpose as best it can, but - perhaps even more important - should trigger feelings.

Even if the finished product is the instrument for truth finding, the fact that the production of constructional reality must be preceded by a process is important. And so the cycle between reality and truth closes: The thought of analysis requires reality, the thought of synthesis requires truth. Building reality means building for truth. As part of the university course "experimental building" I realized a great number of projects in recent years, using a wide range of materials and pursuing different aims. All of these projects were designed, planned and built by us. We built pieces of furniture and stage sets, exhibitions and bridges, emergency shelters and an amphitheater.

Each work we realized confirmed the accuracy or, in some cases, the inaccuracy of our decisions and definitions, never hesitating to tell the truth about it, downright and unambiguously. The following figures will illustrate this statement, adding a visual dimension to the purely verbal.

Fig. 3 Bridge made of roof battens, span: 8 metres (The truth about efficiency).
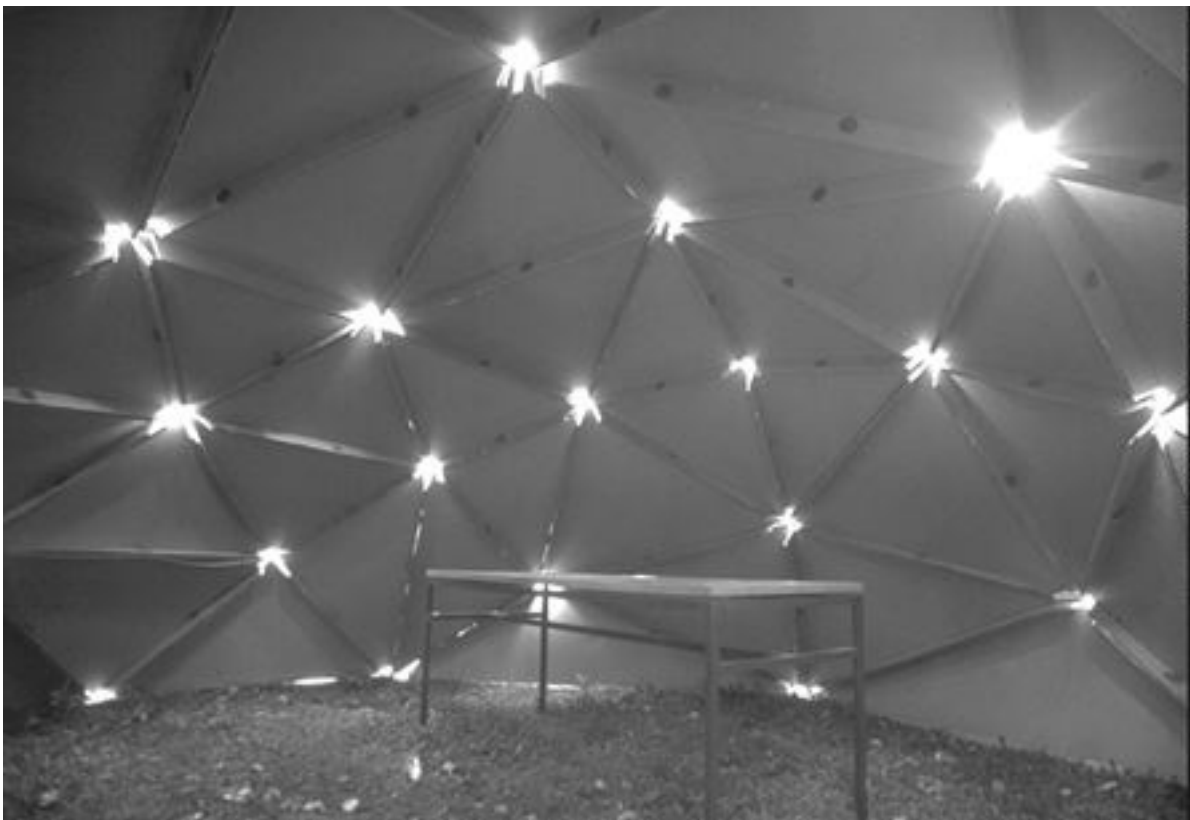
Fig. 4 Dome made of corrugated cardboard (The truth about light).
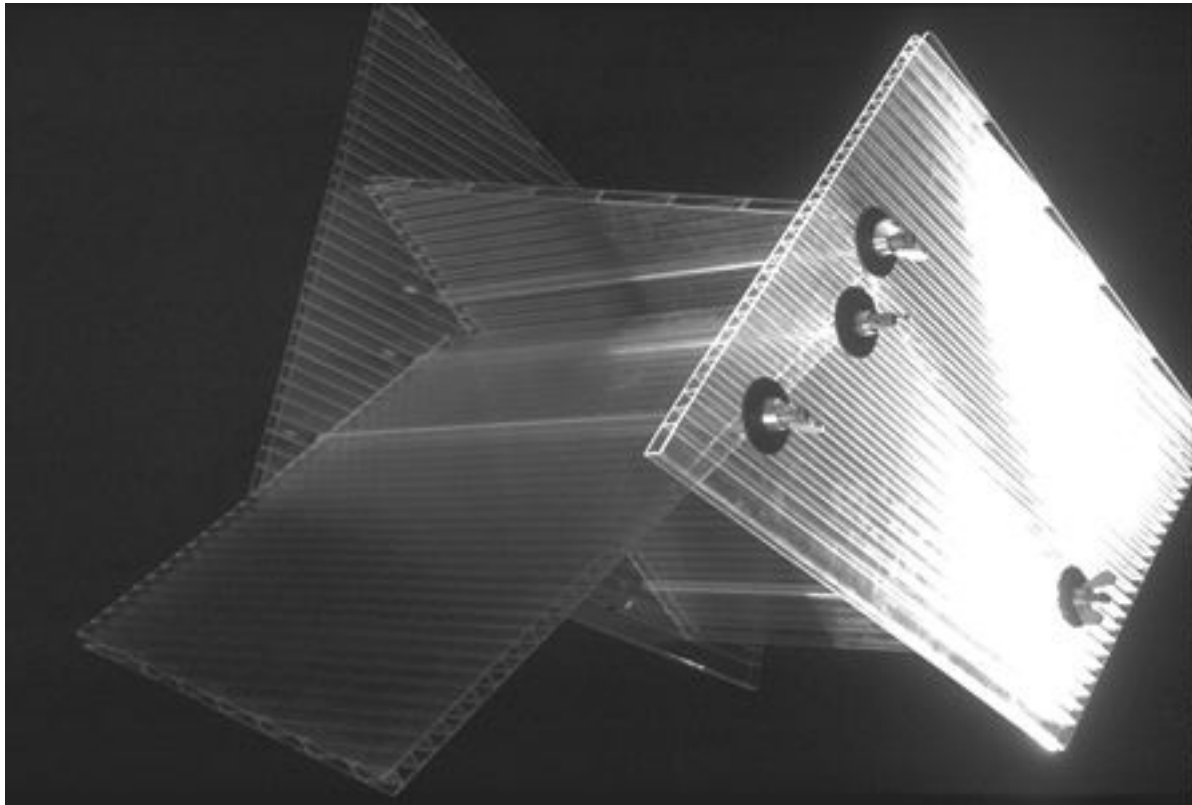
Fig. 5 Chair made of .... (The truth about a material).

Fig. 6a-b Residential building instead of slum (The truth about the bottom line).

Fig. 7 The truth about detail.
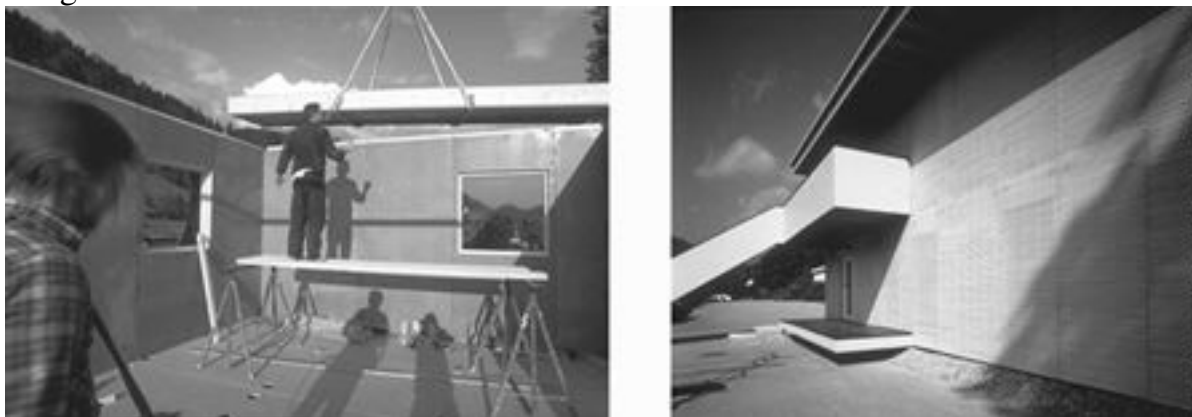
Fig. 8a-b Residential piece in Übelbach, modern technology in multi-storey residential building (The truth and nothing but the truth).

Fig. 9 Building with clay (The truth about ourselves).

II

ARCHITECTURAL PSYCHOLOGY

Lost in Space?
Architectural Psychology - Past, Present, Future
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Environmental psychology as a scientific discipline originated in Europe. From 1904 to 1939, *Willy Hellpach* published contributions on nervousness and civilization, on people in modern cities, and on other environmental issues. With the forced emigration of *Kurt Lewin* and others, environmental psychology came to the United States. A scholar of Lewin, *Roger Barker*, did classical field studies on standing patterns of behavior and behavior settings in a small town of Kansas. American pragmatism and quality control were favorable to the new field, contrary to old Europe, where the number of specialists is still very limited, and evaluations rare.

Architectural psychology is the *psychology of built* (mostly urban) *environments*. In German-speaking countries, it is one ""old leg" of environmental psychology, the second one being *psychology of environmental protection*. A methodological review by Kaminski (1995) summed up five *perspectives* in environmental psychology - patterns of spatial distribution, everyday jigsaw puzzles, functional everyday action systems, sociocultural change and evolution of competence.

Having been used earlier in the United States (e.g. [1]), the term *architectural psychology* was used as title for a publication on the Strathclyde conference of 1969, and was introduced in Germany as a translation for "Bauwelt Fundamente" [2]. Another conference under this title took place at the University of Strasbourg [14]. Ten years ago, a German architectural data base analysis on architectural psychology listed 47 books and articles since 1976 [8].

Starting with Strathclyde, architectural psychology has come to age and passed its 25th birthday. Thus, a triangulation of its position, especially in Central Europe, seems interesting and necessary. A recent *survey* mainly on *university projects* in German-speaking countries [16] found a decrease of studies about the psychology of built environments. 25% of all projects were reported in a category which back in 1975 had made up 40%. This means that in the rapidly expanding field of environmental psychology (13 -uncoordinated!- workshops and poster sessions on environmental topics including only 2 on architectural psychology are registered for the Munich DGPs conference in October 1996), the proportion of built environment-studies *dwindles* relative to the environmental protection field. Günther, in his unpublished

survey of BDP (Association of Professional German Psychologists) *members*, found only a handful active in architectural psychology - mostly part-time, not full-time.

A discrepancy between the "high interest" displayed by planners and a very *low institutionalization* was noticed in Germany by Kaminski [11], and is even stronger in Austria, where no psychological institute exists at a university of technology (in Germany and Switzerland, there are several). Consequently, in 1996, Austria has only two full-time architectural psychologists both outside technical and arts universities.

Looking into the first *German handbook* of environmental psychology [15] published 3 years after the US Stokols & Altman handbook [17], you will see that *architectural psychology* is "*everywhere and nowhere*" - it comes to the surface in the editorial, under human geography, under phenomenology, the ecological optics of Gibson, and environmental representation. Not terminologically, but as a *background concept*, it is quoted in environmental cognition (part 5), space and motion (part 6), environments and users (part 7), special environment: the city (part 8) and environmental planning and design (part 9). When turning the pages, I had the impression that an interested architect trying to find the links between architecture and psychology must come to the conclusion that they are "lost in space". Main fields present in the 1990 handbook are *spatial and environmental perception* and the psychological implications of *housing*. Two books summing up German housing & psychology are from Flade [4] and Harloff [6]. Repeated research activities come from Tübingen, Berlin, Magdeburg, Darmstadt, Bern, Vienna and Salzburg.

How is the *international research situation*? Using the SSCI, PsycLit, Psyndex, ICONDA, BIP, VLB, DA and SOLIS/FORIS data bases, the author collected articles and books resp. -chapters on architectural psychology and related fields in German- and English-language countries mostly from 1990 to 1996 [19]. SSCI is the main social sciences data base issued by ISI (USA). PsycLit is produced by the American Psychological Association. Psyndex comes from Trier, and covers German-language research material. ICONDA is compiled at IRB Stuttgart, and a special planner and architecture data base. BIP stands for English-language books in print, VLB is its smaller German-language cousin. DA offers Dissertation Abstracts, and SOLIS / FORIS social & economic sciences.

Fifteen keywords were searched for in all data bases. Table 1 shows the results of 7 data bases [1]. What is no longer striking after our handbook findings - architectural psychology as term is almost non-existent, except in

ICONDA. Again we have to notice that most of architecture & psychology sails under other flags. Looking for psychology and architecture, you can find more under housing quality or built environment*. Checking the SSCI entries for "architectural", it was found that from 1991 to March 1996, 37 research articles were covered, of which 6 (15,4%) were from psychologists on psychological topics (design process, legibility, architectural preference / education). This is not bad compared to the new field of virtual reality where, in the same time, only 2 of 34 research articles (5,9%) were from psychologists. One of the two was published in Japanese language.

Keyword	SSCI	PsycLit articles	PsycLit books	Psyn-dex	ICONDA	BIP	DA	Sum
architectural	116	96	96	48	>1000	1331	976	>3000
architect. psychology	0	0	0	3	14	1	0	18
design & psychology	9	1	1	0	171	0	0	182
simul & psychology	2	2	2	0	7	0	0	13
simulation research	2	5	5	2	-	35	6	(55)
housing quality	10	8	8	8	127	10	10	181
urban quality	1	2	2	5	12	41	0	63
full-scale model*	0	1	1	0	15	2	2	21
built environment*	40	22	22	2	297	46	89	518
post-occup.evaluation	0	3	3	1	52	0	5	64
user needs analysis	0	0	0	0	24	0	0	24
space perception	6	23	23	22	4	43	3	124
spatial simulation	0	1	1	0	0	1	4	7
spatial quality	0	0	0	1	8	4	0	13
virtual reality	84	26	26	10	49	113	1	309

Table 1. Prevalence of 15 keywords in 7 data bases.

Coming from the planners' side, the ICONDA data base registered 14 entries on *architect(ural) & psychology* from 1976 to July 1996. Five came from architecture journals, two were books written/edited by psychologists (Canter, Geisler), two were meeting reports (Strathclyde, Strasbourg) and only one a psychological research article. Apparently, the filter of ICONDA did not let in very much. In comparison, 49 entries on *virtual reality* were listed, 33 of which came from the USA.

As this contribution is related to *full-scale modeling*, it is of great interest how much of international research work is present in the data bases. The answer is brief regarding SSCI - no entry. Even the broader search range of *simulation* produced almost a blank. 15 entries were found at ICONDA, with

a focus on technical simulation - 3 times aerodynamics, 6 times engineering and seismology (e.g. on offshore drilling platforms), but also 3 full-scale reports from Denmark and England.

The studies found by the data base search do not outline an "old, settled" discipline, but rather the sketchy, random, arbitrary surface of a field always "starting anew". As a recent example, discussions at the 2nd EAEA conference (1995) showed that several good architectural simulation studies since 1973 caused no major impact upon planner's opinions and were almost unknown [13]. This weak tradition is also due to a lack of review articles, handbooks and other compendiums - major sources are Kaminski [9], Korosec-Serfaty [14], Geisler [5], Flade [4], Kruse, Graumann & Lantermann [15], and Fischer [3]. The connections to health psychology were monitored by Keul [12].

"Re-inventions of the wheel" are also caused by the lack of joint meetings (except the 6th EFA conference 1996, of course) and of interdisciplinary infrastructure in German-language countries (contrary to the United States). Organizationally, IAPS in Europe does not play such an integrating role as EDRA in the USA. Social pressures building up on architecture nowadays by inter-European competition, citizen activities and wishes for informed consent in most urban projects should not result in drawbacks of interdisciplinary efforts, but form a new challenge for urban planners to cooperate efficiently with social scientists. A working group for architectural psychology (Keul-Martens-Maderthaner) has been active since 1994 and produces a quarterly German-language newsletter ([Orts:Sinn]) that goes to 240 people. A promising project is currently running at Salzburg - the Chamber of Architecture for Upper Austria and Salzburg ordered an image study on self-image and external image of the architect by the public, the media, and decision makers.

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[17]   1280 Entries obtained from 6 of the 8 data bases (except the DA and the -blank- SOLIS-FORIS search) are available on 3.5 inch disk at the Univ. of Salzburg, Insitute for Psychology, Hellbrunner Straße 34, A-5020 Salzburg.

Design By Competition: Looking at Competition Architecture through Time

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Abstract

Research consistently shows differences between what architects and the public like. To the question of whether architects (the experts) lead public tastes over time, we only have anecdotal evidence. This paper discusses two historiometric studies of competition architecture through history. One looks at the record of „masterpiece" buildings derived from frequency of citation in books and encyclopedias. Few result from design competition. The other study had architects and non-architects judge photos of competition winning and competition losing designs through history. Both groups preferred more losers to winners. The paper discusses the implications for further research and for the running of competitions.

We have seen an increase in the number and cost of design competitions for the delivery of public buildings [1]. Because design competition architecture occupies public space, uses public money, and affects the ordinary person's experience of their surroundings, it should be accountable to the public. Architectural associations such as the AIA or RIBA often call for a jury dominated by architects, even though research shows major differences between architect and public preferences.

In a series of studies of a highly publicized design competition (Peter Eisenman's Wexner Center for the Visual Arts), we found that public opinion data of the entries disagreed with the jury choice and accurately predicted subsequent public opinion of the completed building. Many people believe that architects lead public opinion, and that following public opinion on visual form will yield mediocre results. For example, Corbusier said that the public had to be re-educated, and others have wondered about the vulgarity of designs for the public and asked whether architects should take these architectural tastes seriously [2]. According to this view, competitions judged by architects should deliver better buildings, artistic masterpieces. Some competition buildings, such as the Sydney Opera House or the Eiffel Tower, now convey a positive image. While authors have argued that competitions produce some successes [3,4], they fail to define or measure success.

Because of the public nature of competitions, I have argued for the use of public opinion data as information for a design jury [5]. Such scientific research could have a potential flaw. If initial reactions to a building change with exposure or change over generations and if designers lead public taste[6], then designs based on cross-sectional studies of popular preferences would not stand the test of time. The research would not have captured long-term evaluations of the building.

We also lack solid evidence that architect judgments has a bearing on future appraisals. In less than twenty-five years, taste standards for architects shifted from modernism to post-modernism to deconstructivism, and they continue to shift. Anecdotal evidence for 20th century architecture suggests a strong and long-lasting public distaste for "high" style architecture. Recent studies confirm public dislike for "high" style designs [7, 8, 9, 10].

Otherwise, we have anecdotal speculations--reports of reactions to individual artists and works--about the long-term accuracy of expert judgments. Gans pointed out the flaw in these compelling high culture arguments [11]. He suggests that some people pit the best of the "high" culture (the Vietnam Memorial, the Eiffel Tower, Sydney Opera House) against the worst of "popular" culture (velvet paintings or the American commercial strip). This selective sampling ignores poor or mediocre high culture products as well as successful "popular" culture products. Anecdotal arguments do not serve as a basis for building knowledge. We need to know the proportion of successes to failures for competition winners and other designs. This paper is a preliminary look at such historical data empirically.

The scientific approach need not be locked in time [12]. "Historiometric inquiry" applies the scientific method to historical data to uncover general laws over time [13,14]. It represents the intersection of psychology, science and history [15]. Following the scientific method, it: 1) defines and samples the "unit of statistical analysis"; 2) operationalizes "the crucial variables under investigation"; 3) calculates "relationships among these variables"; and 4) uses "statistical analyzes to tease out the most probable causal connections." [16]

The approach is nomothetic in seeking general laws. It differs from much environment-design research in its focuses on the historical record as its source of data. It also differs from other historical endeavors, that are idiographic (focusing understanding the particular). In one historiometric study, Simonton identified composers and compositions that stood the test of time [17]. By comparing the note structure of more than 15,000 themes, he quantified attributes that differentiated the masterpieces from lesser works. Other resear-

chers have used historiometric methods to examine cultural meanings of Swiss housing [18], evolutionary trends in gothic architecture [19], and historical precedence for street design [20].

Historiometric inquiry, used along with other methods, can provide a validity check. For competitions, it add the time dimension and provides a check on the present data showing public distaste for the Wexner Center and more generally for architecture liked by architects.

A Study of Masterpieces

In the first of two studies, we compiled a list of 80 architectural masterpieces. We defined a masterpiece as a building frequently cited by experts on architecture. The final list included buildings cited in at least three of the five encyclopedias, and it included the buildings with the most amount of space devoted to them. We expanded the list by looking at the frequency of citation of architecture in books on architecture in the twentieth century.

Checking the history of each building revealed that only three of them resulted in part or whole from a competition. In one case the praised design had lost the competition (Saarinen's Chicago Tribune entry). The proportion of masterpieces (3 out of 80) seems small and suggests that, at least historically, competitions may not result in masterpieces. However, we can only make tentative inferences from the numbers, because we do not know the proportion of buildings (or major public buildings) that result from competitions, the proportion of leading architects who avoid competitions, or the proportion of winners early in their career. For additional information, we examined the responses of present day observers to competition winners and losers through history.

Present Day Responses to Competitions Through History

A pilot study had examined student responses to award winning designs vs. other designs over time. Looking at citation winning and non-citation buildings published in *Progressive Architecture* between 1930 and 1990, the study had found that architectural students and non-architectural students did not favor citation-winning designs to the others [21]. In fact, the architecture students reported higher preferences for the non-citation buildings and the non-architects gave neutral scores to both kinds of building.

Would similar findings emerge for a comparison of competition winners and losers? The present study expanded the pilot study to consider adult reactions (both preference and judgments of good design) to competition architecture.

Selecting Competitions. We selected competitions from a 104 year period from 1882 through 1986. For that period, we paired each of twenty-five competition-winning designs with a loser in the same competition. To develop this sample, we searched journals and books for competitions for images showing competition winners and losers. The search uncovered ninety competitions with published images of both winners and losers. Experimental controls reduced the sample to fifty usable competitions from 1882 through 1987: Because variations in mode of presentation (drawing, model, photo of completed building) or viewing angle might affect response, we retained only those instances with similar modes of presentation and similar viewing angles for the winner and at least one loser. We initially sought five examples from each decade from 1880 through 1990, but only two decades (1921-1930 and 1980-1990) had an adequate number of paired winners and losers. We combined four competitions from 1882 through 1903 with one from 1916 to get a 34-year category (1982-1916). We joined two competitions from 1930 and 1931 with three competitions from 1946-1947 to make up a 27-year category. We also joined three competitions from 1956 with two competitions from 1965 and 1967 to make up an 11-year category. This yielded five pairs of competition winners and losers from each of five time periods: 1882 to 1916, 1921 to 1929, 1930 to 1947, 1950 to 1967, and 1981 to 1987. The sample included a handful of famous competitions--the Reichstag (1882), Helinski Station (1903), Stockholm Town Hall (1903), Chicago Tribune (1922), and Humana Building (1982). It included fourteen different building types and one building-type (housing) present in each time period, including six houses, three corporate buildings (two of which were towers), two government buildings, one civic center, two stations, two libraries, a bank, an embassy, a diplomats' club, a chapel, two museums, an auditorium, a museum/auditorium, and a memorial.

Selecting   Respondents. We had 50 practicing architects and 50 non-architect professionals in Columbus, Ohio evaluate the designs. An interviewer visited twenty-one architecture offices and twenty-one non-design offices nearby the architecture offices. In each group, 90.4% of the firms agreed to participate. The participating firms provided between one to eight persons for interviews, with most firms (92%) providing fewer than five respondents. The groups were similar in age (averaging approximately 42 years old) and years of practice (average of approximately 16 years). Reflecting the actual professions, the architect sample had a higher proportion of males. The non-architectural group included engineering, accounting, marketing, management, communications, teaching, school administration, insurance, nurses, radiologists, counseling, federal investigation, writing, pharmacist, chaplain, social work, optician, loan processor, and banking.

Survey Form. We created booklets with each winner in a plastic folder next to the loser of the same competition. We randomized the orders of presentation of the building pairs; and for each pair we rotated the location of winners and losers. Half the time a winner appeared on the left and half the time it appeared on the right. We matched these arrangements for the architects and non-architects. The respondent would only see one pair at a time. The interview obtained ratings of preference, best design, building recognition as well as background information on gender, year of birth, and years in practice. In each group, half the respondents received the preference questions and half received the „better design" questions first.

We found consistent responses for the full sample and for the architects and non-architects taken separately. There was high inter-observer reliability scores on liking (alpha = 0.89) and better design (alpha = 0.85). We also found high inter-observer reliability within each group. This evidence of consensus supported the use of the composite scores for the full sample, and for each group.

Our examination of building recognition showed that it did not bias responses. Few respondents reported recognizing the buildings. The analysis tallied the number of respondents indicating that they recognized a building. For all but three competitions, fewer than 5% of the sample said they recognized a building. For the Chicago Tribune Tower (1922), ten respondents said they recognized the winner and eight said they recognized the loser; for the Harding Memorial (1925) ten respondents claimed to recognize the loser; for the Human Tower (1982), twelve respondents said they recognized the loser, and four said they recognized the winner, and an additional thirteen claimed to recognize both. Inspection of responses to the recognized buildings suggested that recognition did not skew ratings. Dropping responses to "recognized" buildings did not change the pattern of results.

Results. Did the respondents evaluate the winning entries more favorably than the losing entries? No. They favored the losing entries. The full sample of respondents selected significantly more losers (1378) than winners (1118) as preferred, and significantly more losers (1351) than winners (1144) as the better design ($X^2 = 27.08$, 1df, $p < 0.001$; $X^2 = 17.18$, 1df, $p < 0.001$). Analysis of the responses of the architects and non-architects separately confirmed the pattern. Significantly more individuals in each group selected more losing than winning entries as preferred and as better designs. The non-architects chose a significantly higher proportion of losers to winners as preferred (59%) than did the architects (51%), but each group chose more losers than winners. A similar pattern emerged for judgments of the better design. Each

of the interactions achieved statistical significance (Preference: $X^2 = 16.56$, 1df, p < 0.001; Better Design: $X^2 = 9.172$, 1df, p < 0.01).

The pattern also held for comparisons over time. For all but one time period (1950-1967), significantly more respondents selected losers than winners as preferred. Significant differences emerged for comparisons of buildings in 1882-1916, 1930-1947, and 1981-1987. In each case, respondents chose more losing entries than winning entries as preferred. For better design a similar pattern emerged. In all but one time period (1921-1929), respondents selected more losers than winners as the better design. These differences achieved statistical significance for 1882 - 1916 and for 1981-1987. In each period, respondents chose significantly more losing entries than winning entries as the better design.

The results also confirmed the familiar pattern of differences in response between the architects and non-architects. For two periods (1921-1929, 1930-1947, more architects (compared to non-architects) chose winners while more non-architects (compared to architects) chose losers as preferred and as the better design. For another period (1956-1967), the pattern reversed: Relatively more architects chose losers and more non-architect chose winners as preferred and as the better design. In the last period (1980-1986), relatively more architects chose winners and more non-architects losers as preferred. Equal numbers of architects chose winners and losers as the better design, but more of the non-architects chose losers as the better design.

We repeated the tests for the one building type-houses. These tests centered on six competitions: one house competition in each period except one that had two house competitions. The results agreed with the earlier results. For preference and better design, significantly more respondents chose losing than winning entries for 1882-1916 and 1981-87. They chose more winning entries than losing entries for one house competition in 1930-1949.

Conclusions

The results do not support the view that architects, as seen through competition juries, lead public taste or select lasting masterpieces. Only a small proportion of „masterpiece" buildings resulted from design competitions; and architects and non-architects preferred losing entries to competition winners through history.

The second study only looked at visual impressions of images of the buildings. A more complete analysis would examine space, functioning and overall performance of the competition winners compared to non-competition

buildings (of similar type and age) over time. Although historical data of this sort is not available, we can start to create it by gathering such information on competition winning designs. Further research could compare competition-winning designs with the full sample of losers or with non-competition designs.

If the same pattern of results hold, that would suggest different procedures for running competitions. We might change the composition of juries to include other experts involved in building delivery and upkeep and to involve representatives of the public. The sponsor could obtain and present public opinion data to the jury.

Unlike art in a gallery or a secluded house, competition architecture is highly public. It involves public money, occupies a public site, and it affects passersby and occupants. As a result, this form of building must work for the public. It must work functionally, technically and aesthetically. By trying different procedures and evaluating their performance for the productivity of the competition (getting the entry built) and the performance of the completed buildings, we can improve competition performance for the clients, competitors and the building users.

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Evaluation of the OSLD System

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> "Architectural methods, on occasions, resemble scientific methods; in architecture you can adopt a research process similar to those used by science. Research in architecture can become more and more methodical, but its essence will never become exclusively analytical. In architectural research you will have more instinct and art." [Alvar Aalto]

Introduction

Venezuela, as most of Latin-American countries, tries to develop proposals for low-cost housing, adaptable to geographic and climatological diversity, as well as to the different requirements and characteristics of its inhabitants. One of the factors that influence most in obtaining low-cost units is building in large scale, it is therefore important that any proposal for a particular system should go through exhaustive studies and research. For this reason, it is convenient to test proposals in order to obtain prototypes with best performances. For these tests, full-scale modeling has simulation potentials comparable only with those of actual building, becoming a more powerful instrument to visualize spaces than drawings or even computer graphics.

Object of Research

In a *National Competition* of low-income housing, carried by INAVI (National Institute for Housing) in 1993, our office [Otero, Sanabria, Luchsinger, Denjoy Associate Architects] won the first price competing with 30 other participants. The solution offers the users the possibility of satisfying their basic family requirements and allows the expansion of the unit when the family composition grows. The system proposed is based on a unit of 36 m2 in two floors which can be expanded to 72 m2 as part of a multiple dwelling building. The unit is contained in a cube whose side is 6 m, defined by an structural module of 3 m. Initially the house uses 75% of the ground floor and 25% of the upper floor. The unoccupied areas function as terraces or double heights that can be incorporated as internal spaces when needed. Expansions are carried using light structural slabs and wall panels. This basic unit can be joined with other units in many different positions to solve multi-family buildings of different sizes and shapes, depending on the availability of lots. One can build detached houses, town -houses, multiple story buildings, either in flat surfaces or in slopes, according to the topography or you can also build an homogeneous organization of units one on
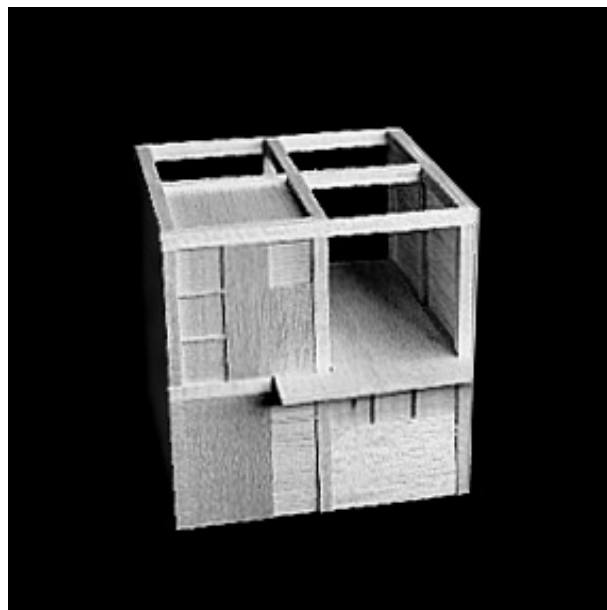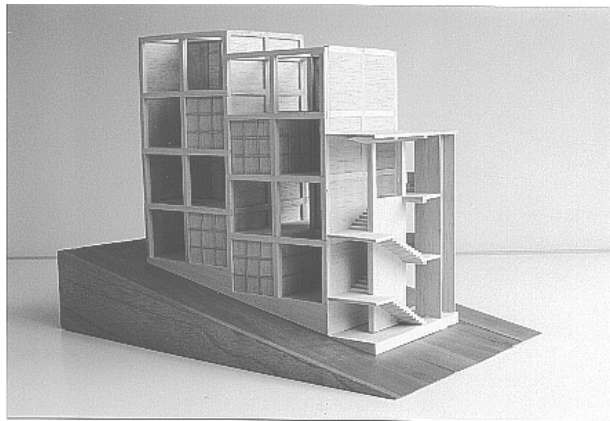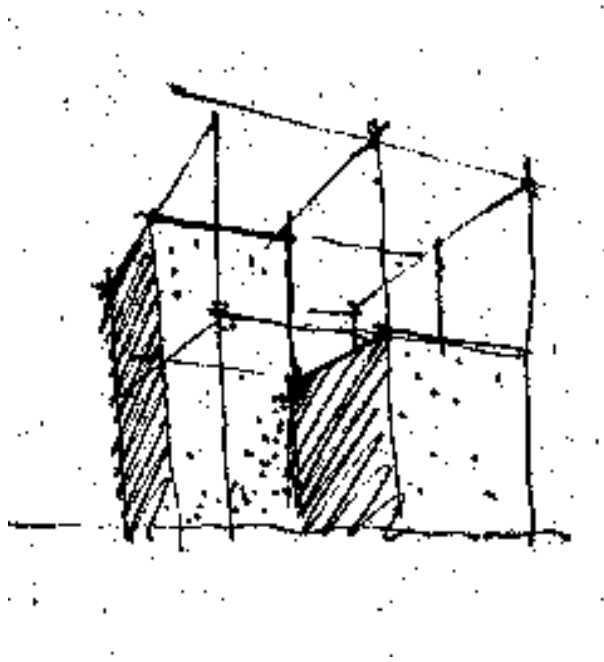
Fig. 1a-c The main concept.

top of the other to form apartment blocks of six stories high, built by super-imposing three apartments, without the use of elevators. The proposal can be built either in concrete, steel, wood or any other material or technology available, depending on the region and particular requirements of each problem. This research consists on the evaluation of this basic housing unit that can be expanded, both on single or multiple-story buildings. This unit was designed for people with very low income, so that cost is a top priority in design decisions.

Before INAVI actually started building these units using the OSLD System, it was considered necessary to simulate the basic unit using the full-scale model in order to:

- Test spatial and morphological characteristics of the unit by measuring their spatial quality;
- Experiment different options of windows and furniture in regards to the influence of the variable height: 3 m, which has never been used in Vene-zuela for this type of housing;
- Experiment different options of expansions, from 36 to 72 m2 and to test how they affect their spatial quality.

This research has three main objectives:

- To identify spatial characteristics of the basic unit and evaluate its spatial quality;
- To determine the capability of the unit to be expanded or modified, by using different types of walls, windows, furniture, objects and plants;
- To inquire about the influence of the level of realism in the perception of the different spaces.

It is necessary to define first the *variables* that need to be tested:

Spatial Quality: It is an opinion of many architects that it is a subjective con-struct which reflects, among other things, the psychological impact that spaces produce on observers and users, as well as judgment about the character of space, their proportions and their adequacy for intended activities within spe-cific contexts.
Spatial characteristics: It refers to dimensions and space relations such as or-der, rhythm and spatial configuration.
Possibility of change and expansion: It refers to the options allowed by the geometry of the basic unit and its structural and spatial module.
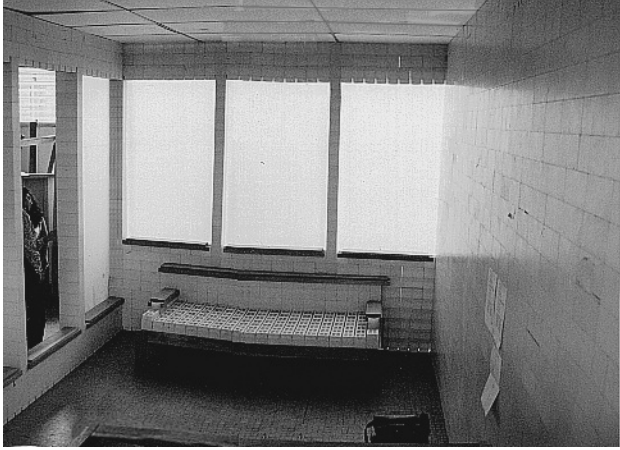
Fig. 2 Ground floor without plants: The space was appraised as open (5), pleasant (5), Clear (5.5), roomy (5.5), warm (5.5) ordered (5.5), welcoming (5.5) vacational (6.5) and tropical (6.5). Only two adjectives had negative connotations: small (2). and normal (2.5). People liked the apartment (5).

Fig. 3 Ground floor with plants: Most of the adjectives improved their ratings: open (6), happy (6), pleasant (6.5), clear (6.5), Interesting (6.5), roomy (6), warm (6), ordered (6.5), welcoming (5.5), vacational (7) and tropical (7). People liked the apartment very much (7).
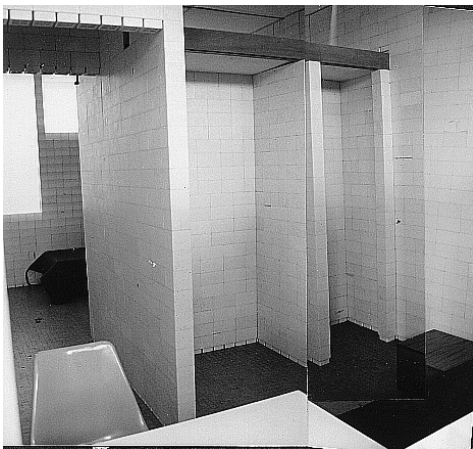
Fig. 4 Upper floor: The following adjectives were appraised on extreme ratings: pleasant (6), clear (7), ordered (7), vacational (7), tropical (6), static (1.5) and normal (1). People were not sure whether they liked the apartment or not (4).

Design Research

The strategy chosen was to:

- Simulate on the real scale model the housing unit;
- Evaluate the spatial quality of its component and analyze results;
- Modify the model in order to improve negative appraisals and evaluate again their spatial quality;
- Build three units at 1/10 scale to show expansions and modifications of windows and furniture;
- Compare the three models using the same group of judges;
- Analyze results and derive conclusions.

In order to carry on the design research, first it was necessary to build an instrument that could measure spatial quality. It was based on the Instrument for Measurement of Psychological Impressions (IMIP) developed by Luis La Scalea [2] and used in most of the evaluations in our Laboratory. The IMIP consists of a semantic differential instrument [3] of 11 pairs of adjectives grouped in three factors: affective, dimensional and social. The new instrument introduces 10 new pairs of adjectives chosen by a representative sample of architectural students and staff. It was believed that they allow more ample and specific value judgments. The adjectives are:

Affective factor: It refers to emotive responses produced by the perception of the space. Sad-happy, pleasant-unpleasant, boring-interesting, cold-warm, beautiful-ugly, welcoming-rejecting.

Social factor: It refers to beliefs and values socially shared. Ordinary-refined, elegant-tasteless, vulgar-distinguished, sensual-martial, normal-special, rural-urban, permanent-vacational, Nordic-tropical, pagan- mystic, static-dynamic, ugly-beautiful.

Dimensional factor: It refers to the way attributes such as shapes, sizes and pressure, affect people. Close-open, oppressive-spacious, confusing- plain, big-small.

Besides the three factors described the constructs were also used: I like it, I do not like it, as a mean of providing an overall evaluation. The sample was chosen between students of architecture of different grades. Forty five subjects participated in the selection of the extra 10 pairs of adjectives. For data analysis a group of students registered in one of the subjects of the Laboratory ("Spatial Design Ability") were chosen and trained in the use of the instrument and on basic statistical analysis.
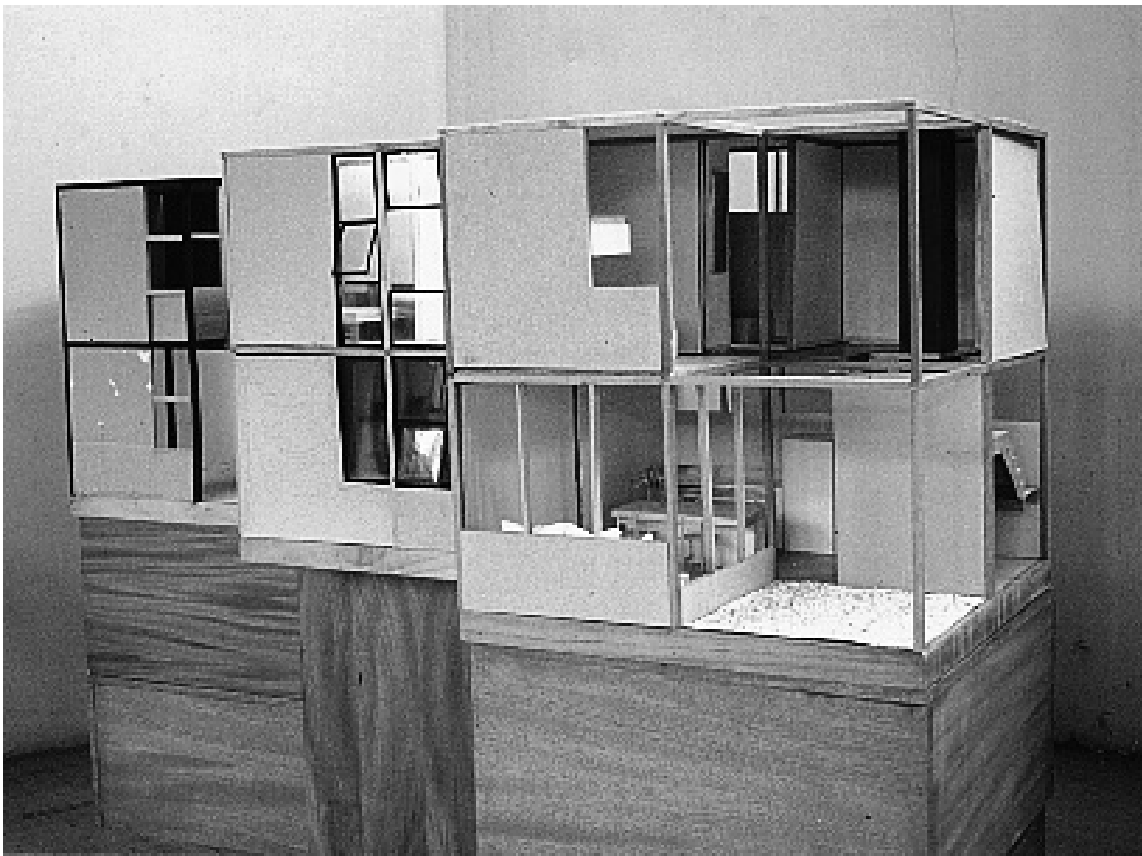
Fig. 5a-b.
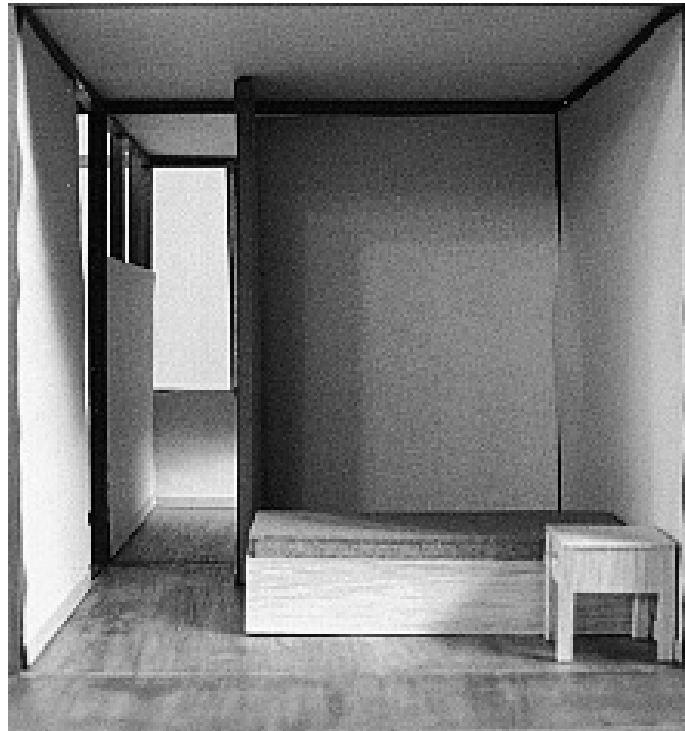
Fig. 5c.

Procedure

First of all the ground level of the unit was built by a group of students, departing from the original plans of the apartment. Our laboratory does not have sufficient height to allow the construction of the whole unit (6 m) at a time. Then the upper level was built. The simulations showed the initial stage of the ground floor and the expanded stage of the upper floor. It took about 6 hours to build the two levels of the unit.

Secondly groups of 8 students evaluated the spaces at a time; they were instructed on the use of the instrument and were asked to walk through each level and evaluate it. These sessions lasted 15 minutes and they evaluated first the ground floor without plants, then with plants and finally the upper floor without plants.

Thirdly three group of students built one model each at a 1:10 scale, following instructions about which elements would remain unchanged. Walls should be removable in order to allow visualization and possibility of taking photos. Models were built in one week, then the three groups redesigned the unit in order to obtain specific intentional character. Thus, group A tried to build a unit that could be read as austere and simple; group B, roomy and clear and group C, elegant, actual and vacational. Discussions about results and possibilities of the unit were drawn and important recommendations came out to improve both the unit and the System.

Adjective	Related to
Open	Height of the spaces, large windows, space configurations on L enclosing the patio, fluency of the space due to the double height
Clear	The structural order of the unit. The module can be read either horizontally and vertically
Interesting	Variety of the elements and viewing possibilities of the space
Warm	In spite of the apparent coldness of the materials of the RSM, the proportions of the space and its relation with the patio, rated them as warm spaces
Dynamic	Possibilities of movement by user: between floors and through the patio as well as the suggested multiplicity of the social area
Tropical	The height of spaces, the large sizes of windows and the patio. Even higher once a hammock and palm trees were added to the scenario

Table. 1.

Simulation of the upper level of the housing unit: It had high ratings in the adjectives pleasant, clear, orderly, vacational and tropical. Probably they are consequences of the proportions, height, size and location of windows, and the easily understandable structural module used.

Adjective	Related to
Pleasant	Lighting, balance, coherence, proportion and order
Clear	Fitting between function, form and spatial relations
Ordered	The orthogonality and the geometrical arrangement of the spatial elements
Vacational	The absence of personalized elements on the arrangement
Tropical	Windows and space height are bigger than those usually used
Static	Due to these spaces are designed as permanence one, terminal spaces
Normal	The conventional typology of spaces

Table 2.

Conclusions

The simulations of the lower level of the housing unit with and without plant showed that the spaces in themselves were evaluated with positive ratings in spite of the small size of the unit. Those evaluations were enhanced by the use of adequate furniture, colors, objects, specially in the adjectives (table 1).

About the usefulness of the RSM: A house is perceived as a series of space sequences which give personal overall impression of the whole. RSM simulations allow the possibility of carrying activities experience impressions similar to those of real space. In spite of all the information available of the OSLD System, their spatial characteristics and qualities had not been experienced or evaluated. There are components of the space perception that can only be simulated at real scale: the sound reflected in walls and ceiling, the atmosphere, the actual pressure walls, objects and furniture produce; and specially the possibility of having real people carrying on activities and giving real scale to the space. We also think it is a most valuable tool for the process of learning about architectural space.

About the usefulness of the 1:10 scale models:

- It was adequate for representing the two levels of the house particularly to reproduce the double height that links them;
- It allows to record spatial characteristics through the use of video and photos;
- It allows quickly for economic changes;
- It allows the use of color, special furniture and styles;
- It does not allow the possibility of experience sequences or use of space;
- It is not easy to perceive the volume of the space, even if there are reference elements as furniture.

About the behavior of the OSLD System:

- Evaluations showed that size of space were not perceived as small;
- It adapts to different levels of requirements and from different social and economical status;
- Changes in colors, design materials of walls and windows, yielded substantial changes in the image, style and character of the proposal;
- The structural module used, both in plants and elevations, give order to the whole and allow enormous possibilities of coherent combination to group the units or to solve façades;

- It seems interesting to overhang in the façade the cupboard of the bedroom in the upper floor in order to increase the area of the main bedroom.

We believe that direct observation of the behavior of users in particular spaces completed with particular questions, can offer reliable and interesting results, as compared with the use of specific instruments of evaluation, partly because people are not conscious that they are appraising a space and also because you do not have to deal with the correctness of the understanding of the adjectives of the instrument. In this research we used both methods complementary of the other with excellent results. Another important finding of this research is that students can derive spatial grammar concepts from the analysis of the spaces designed or modified, opening new lines of research with direct implications for architectural education.

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Effectiveness of Models

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Introduction

Architects have used many types of models to simulate space, either in their design processes, to show to other people or as final specifications to build them. Although there is some evidence that models can be misleading representations of the real world [1]; many studies have suggested that generally simulations appear to give results similar to those of reality [2]. This exploratory research intends to analyze the variables involved in using the adequate models for specific purposes, mainly for use in architecture. This analysis could offer the possibility to choose more effective models for a required activity. Effectiveness of models refers to the level of performance a model allows to simulate spaces or objects for specific purposes. First, models are analyzed in terms of their use and their types. Then, a number of indicators of effectiveness are considered and finally some models apparently, most used in architecture, are evaluated using those indicators. This evaluation may provide a reference for choosing the adequate model for specific architectural activities.

Use of Models

Models are considered here as physical representations of the real world. In architecture, models can be used as tools in the design process, as presentation tools, as tools for learning or for research [3]. Their use depends on: a.) The objects being simulated; b.) The stage of design a model represents; c.) The view-point allowed by the model; d.) The materials required to build it; e.) The spatial characteristics of the model; f.) The models changeability; g.) The skill of the model maker; h.) The amount of detail required; i.) The number of variables (ventilation, structure, atmosphere) on which the model is required to give information; and j.) The means for the viewer to see the model. The use of models has its limitations, some models allow experimentation with some variables but not with others, some models may take too long to build or may be too expensive. Also models are only surrogates of real space and their verisimilitude cannot be taken for granted [4]. Architects need to work with models in order to visualize their spatial propositions and show them to others. Choosing the correct model requires a knowledge about the types of models available, their performance, their limitations and mainly to have a clear understanding of what the model is intended to achieve.

Types of Models

Models can be categorized in three types:

- Two-dimensional models; drawings, photograph, slides, films, computer graphics;
- Models that yield three-dimensional impressions such as stereoscopic slides, holograms, virtual reality (special computer system);
- Three-dimensional models, such as scaled or full size.

Previous studies [5] have analyzed more then 50 types of models. From these, we analyze in this research: drawings, computer graphics, virtual reality, three-dimensional scaled models and full size models, as according to our opinion, they are basically the most used in architecture at this moment:

1. *Drawings*: are by far the most widely used simulations in architecture and although they are clearly two-dimensional they can express certain three-dimensionality by using techniques such as axonometrics, perspectives, deep sections. They refer mainly to hand made sketches and technical drawings either in pencil, ink, colors or similar materials.

2. *Computer graphics*: have apparently become, in the last few years, the second most used model in architecture either by the student, the architect or the graphic operator (draftsman). The available software allows drawing facilities even to the less experienced. They can be seen directly on the screen of the monitor or in prints. Both computer graphics and virtual reality are interactive presentation tools that can be used to show design alternatives to clients and make changes, almost instantaneously, according to their suggestions.

3. *Virtual reality*: a computer program seen with special equipment that gives the user the sensation of being inside the space and the possibility of manipulating it directly, is probably the most interesting alternative for simulation that has come out in the last two years. Some institutions and schools of design and architecture are using it as a tool for teaching.

4. *Three-dimensional scaled models*: have been used since ancient times to provide means of visualization of spaces; many structures were built by taking measurements directly from detailed models. They allow observers to move around them, so they are also dynamic.Their spatial characteristics offer a sense of depth and atmosphere that seems difficult to obtain with two-dimensional models, but it can also give an unreal impression of the space or object that is being simulated.

5. Three-dimensional full size models: have been used in the last twenty years by some laboratories mainly located in Europe. They allow, according to their size, characteristics and sophistication, the simulation of different types of spaces at real scale and with different levels of realism. They also present a series of limitations related to the module of the wall system used, the type of ceiling, the size, materials, which limits the possibility of exact replications of reality. The use of these models are generally selected by the architects according to their skills or availability and rarely an evaluation is made to determine whether that model was the most appropriate or effective for the intention.

Effectiveness of Models

Effectiveness of models is considered here as *the level of performance of the models* to enable specific intentional activities with the elements of architectural space. Therefore it is *defined in terms of achieving the purpose of the exploration with validity and economy in the use of the resources*. It can be determined by the following indicators : cost, time, changeability, realism, validity, familiarity, attractiveness, projection ability, interlocking ability and ability to select information [1] using specifically defined scales; in most of them, a three level scale defining each indicator in term of low, medium, and high are used as descriptors of each level. These criteria could vary significantly according to the users, the country and other cultural and economical factors.

Cost: three types of costs are considered:

- *Initial cost*: Includes all the items related to building the model;

- *Operational cost*: Includes all the items related to presenting the model for appraisal;

- *Modification cost*: Includes all the items required to simulate changes in the space.

These costs must take in account materials, equipment, software, labor work and electricity. It is obvious that parameters used to calculate factors of use, depreciation or hourly rental of a Laboratory are particular for different countries or institutions. Also labor work and cost of electricity vary even in short periods. To measure this parameters, a survey using architecture students was made, resulting on the following scale:

Scale	Initial Cost	Operational Cost	Modification Cost
low	less than $1	less than $0.20	less than $1
medium	about $5	about $1	about $3
high	more than $100	more than $3	more than $30

Table 1 It can be said that the lower the cost, the higher the effectiveness.

Time: Three types of time are also considered:

- *Building time*: Time required to complete the model;

- *Operational time*: Time required for showing the model;

- *Modification time*: Time required to change part or all of the model.

Scale	Initial Time	Operational Time	Modification Time
low	less than 1/2 h.	less than 1 min.	less than 1/2 h.
medium	about 3 h.	about 10 min.	about 1 h.
high	more than 10 h.	more than 20	more than 3 h.

Table 2 As with costs, the lower the time, the higher the effectiveness.

Changeability: Refers to the capacity of the model to reproduce variations.

Scale	Description
low	means that to make changes the model has to be built new
medium	some of the existing model can be reused to make the changes
high	every part of the model can be reused to make changes

Table 3 Higher changeability means higher effectiveness.

Realism: refers to the amount of details, colors, textures, plants, objects, a model can simulate:

Scale	Description
low	means that the model can not simulate any details
medium	the model can simulate some details
high	the model can simulate all details

Table 4 Higher realism means higher effectiveness.

Validity: is the extent to which findings or reactions utilizing a simulation can be generalized to the real world. It has been called "ecological validity" [6].

Validity is measured using La Scalea's [7] IMIP instrument for psychological impressions: appraisals are analyzed in terms of three factors: dimensional, affective and social. Differences in significance in the three factors are compared in terms of low and high.

Scale	Description
low	means a high difference between the psychological impression perceived using the model and that produced by a real equivalent situation
high	a total correspondence between model and equivalent real situation

Table 5 Higher validity means higher effectiveness.

Familiarity: refers to the previous experience of the user with the type of model (e.g.: A photo may be familiar to a person but not a hologram or virtual reality images).

Scale	Description
low	the user has no previous experience with this model
high	the user has frequent experience with this model

Table 6 High familiarity means high effectiveness.

Attractiveness: refers to the capacity of a model to be enjoyed for its own sake:

Scale	Description
low	impresses poorly for its appearance
high	impresses highly for its appearance

Table 7 Higher attractiveness means higher effectiveness.

Projection ability: Some models cannot show the unreal, that which does not yet exist or is not visible or accessible (e.g.: a foundation, a tension in a beam)

Scale	Description
low	it can not simulate the internal structure of the model
high	it can simulate the internal structures of the model

Table 8 Higher projection abilities means higher effectiveness.

Interlocking   ability: refers to the capacity of a model to relate to others. e.g.: a three dimensional model allows draught simulator (wind tunnel).

Scale	Description
low	it cannot be related to other simulation devices
high	it can be related to other simulation devices

Table 9 Higher interlocking abilities means higher effectiveness.

Ability   to   select   information: Is the capability of the model to give information about specific aspects of the object constitution or components. A drawing may give details of how to build a window, a photo cannot.

Scale	Description
low	it offers no possibilities
high	it offers all the possibilities

Table 10 Higher information selection abilities means higher effectiveness.

A Pilot Example of Measurement of Effectiveness of Models

To study the effectiveness of models, we proceeded in the following way: First, four models, which were considered to be of common use in architecture, were analyzed in terms of the ten indicators by a group of selected judges chosen for the purposes of this research between teachers and students of architecture. The four models that were considered of interest to compare were chosen so that they would give similar information. It would have been very interesting to include virtual reality as one of the models, but our Laboratory does not have that tool available yet. A room with simple elements: doors, windows, furniture, was simulated with the four models.
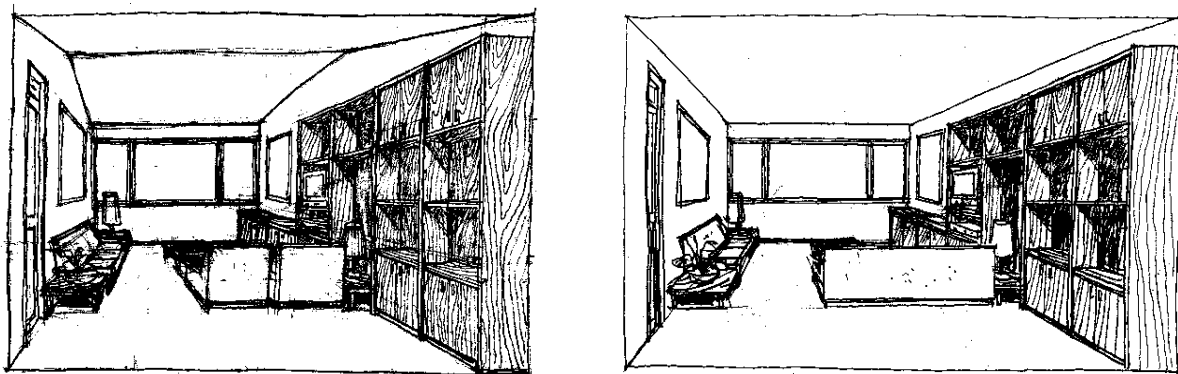

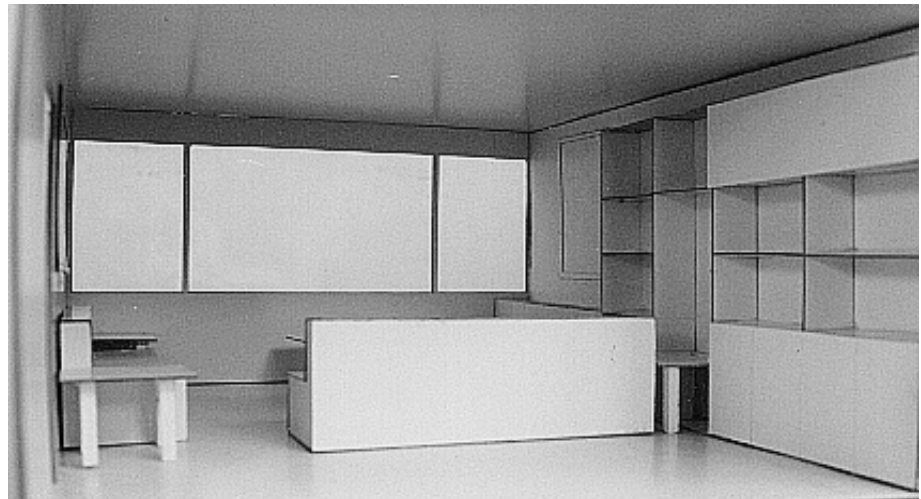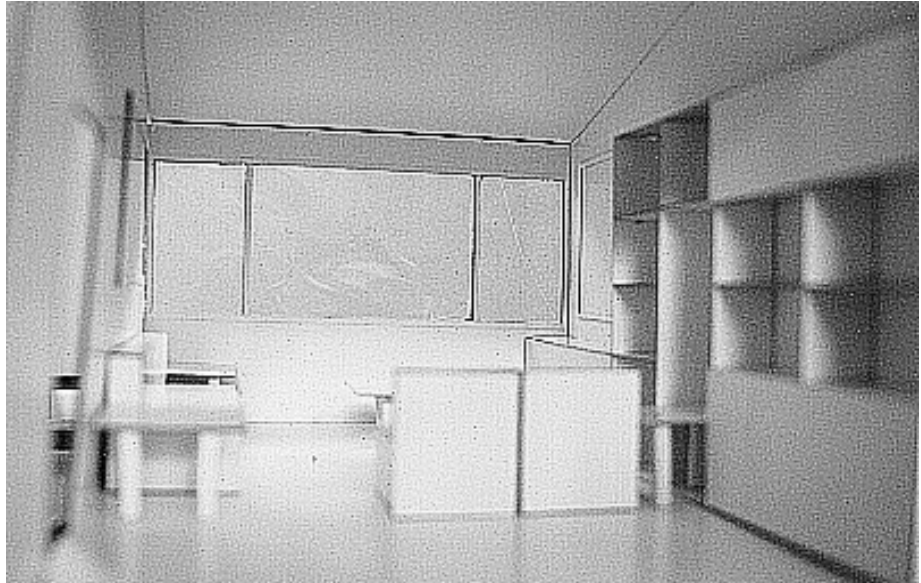Fig. 1a-b Plans, Sections and a Perspective in pencil sketch of the room.

Fig. 2 A walking-through sequence of the room simulated in computer graphics.
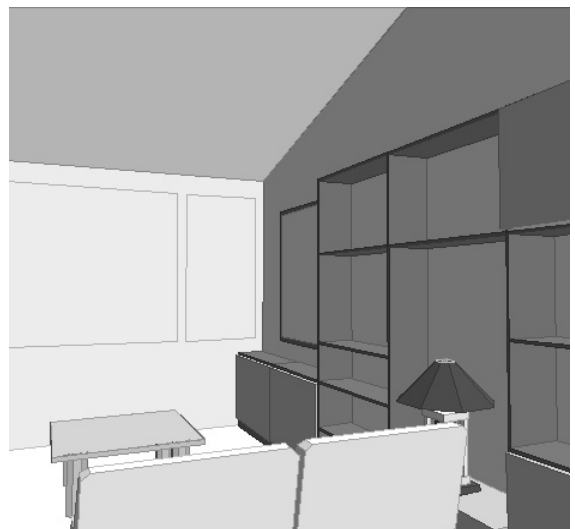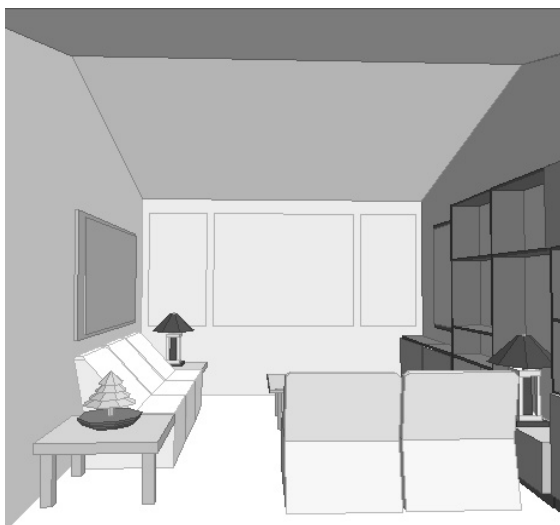

Fig. 3 Three-dimensional changeable scaled cardboard model of the room.

Fig. 4 Full scale simulation of the room.

To evaluate modification time and cost, some of the characteristics of the room were changed: the ceiling, the width of the room, and the size and location of a sofa. A similar sample as that selected as judges for the models choosing, was used to evaluate the previous shown modelations, and its answers can be seen on the following matrix, that shows how the four models are analyzed in terms of the ten indicators.

Indicators of efectiveness	MODELS			
	Pencil Sketch	Computer Graphic	3D Scale model	Full Scale model
Initial Cost (IC)	low	high	medium	high
Operational Cost (OC)	low	low	low	low
Modification Cost (MC)	low	medium	medium	medium
Building Time (BT)	low	medium	high	high
Operational Time (OT)	low	low	low	low
Modification Time (MT)	low	medium	medium	medium
Changeability (CH)	low	high	low	high
Realism (R)	high	high	high	medium
Validity (V)	medium	medium	high	high
Familiarity (F)	medium	medium	high	medium
Atractiveness (A)	medium	medium	high	medium
Projection Ability (PA)	high	high	low	low
Interlocking Ability (IA)	low	medium	high	high
Information Ability (I)	high	high	low	low

Table 11.

In this graphic, as was previously explained, low cost and time means higher effectiveness, on the contrary for the other indicators a low rating means a lower effectiveness. It shows the level of performance of each model, their advantages and limitations. To compare their effectiveness, a second matrix is shown in which the four models are analyzed in terms of their possible performance for specific purposes or activities as: a.) Estate agents showing model of houses to prospective buyers; b.) Participatory design with client: interior decoration; c.) Learning about architectural space; d.) Structural and electrical design; e.) Lecturing about architecture; and f.) Small scale urban design.

Activities	REQUIRED LEVELS OF INDICATORS														Effective Models
	IC	OC	MC	BT	OT	MT	CH	R	V	F	A	PA	IA	I	
Estate agents	M			L				H	H	H	H			M	Comp., 3d Scale
Participatory design		L	M		L	L	H	H	H	H	M				Comp., Full Scale
Learning Arch. Space		L	L		L	L	H	M	H	M	M				Comp., Full Scale
Structural design	M	L	M	M	L	M						H	M	H	Sketch, Comp.
Lecturing on Arch.	M	L	M	M	L	M	H	H	H	H	H				Sketch, Comp.
Urban Design	M	L	M	M	L	M	M	M	M	M	M				Comp., 3D Scale

Table 12.

Conclusions

This is an exploratory research that started in 1979, while doing a Ph.D. in England. Since then, our experience with full-scale model simulation, three dimensional scale models and computers, have given us new insight about the possibilities of their role in teaching and researching on architectural design. We have learned that effectiveness of models is a very complex concept which needs further elaboration. It is necessary to agree on which variables can be generalized and also in the way values are assigned for each indicator. Some models seem to be very effective for many of the activities related to architecture, especially computer graphics, but there are also other models as drawings, photos, three dimensional scaled changeable models, etc., which seem to be also very effective for specific purposes. It is important to continue this analysis in other places, with other groups, in order to have a clearer view of the models that architects will be using in the years to come, and perhaps come out with an effectiveness formula that could make easier the selection of the models for the architectural requirements.

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Real Scale versus Computer Generated: Comparing Models Ecological Validity

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Abstract

This research compares the Ecological Validity of Real Scale Models (RSM) and Computer Generated Models (CGM) as surrogates of a real space in studies of perception. The living area of a low-income housing project in Guatire, Venezuela was modeled in real scale and on a computer walk-through simulator. The real space and the models were evaluated using a the *Psychological Impressions Measuring Test* (La Scalea, 1991), consisting of a semantic differential formed by eleven pairs of opposing adjectives set on a scale of seven levels, that can be grouped in three factors (dimensional, social and affective). The results tend to indicate that both models are Ecologically Valid, however the general perception of the RSM is more similar to that of the Real Space then the CGM. The dimensional characteristics of the real space were well rendered by both models, with the CGM replicating better the Social dimension.

Introduction

Advances in electronic design and communication are already reshaping the way architecture is done. The development of more sophisticated and user-friendly Computer Aided Design (CAD) software and of cheaper and more powerful hardware is making computers more and more accessible to architects, planners and designers. These professionals are not only using them as a drafting tool but also as a instrument for visualization. Designers are building digital models of their designs and producing photo-like renderings of spaces that do not exist in the dimensional world.

The problem resides in how realistic these Computer Generated Models (CGM) are? Moss et al. [1] considered realism as "the capacity to reproduce as exactly as possible the object of study without actually using it". He considers that realism depends on:

- The number of elements that are reproduced;
- The quality of those elements;
- The similarity of replication;
- Replication of the situation.

CGM respond well to these considerations, they can be very realistic. But are they capable of reproducing the same impressions on people as a real space? Research has debated about the problems of the mode of representations and its influence on the judgment which is made. Wools [2], Lau [3] and Canter et al. [4] have demonstrated that the perception of a space is influenced by the mode of presentation. CGM are two-dimensional representations of three-dimensional space. Canter [4] considers the three-dimensionality of the stimuli as crucial for its perception. So, can a CGM afford as much as a three-dimensional model?

The Laboratorio de Experimentacíon Espacial (LEE) has been concerned with the problem of reality of the models used by architects. More specifically, with there Ecological Validity [5] which is the degree in which laboratory results can be taken as reliable and representative of a real situation. Recent research [6] has focused on the problem of the Ecological Validity of the Real Scale Model (RSM). The results found it to be ecologically valid as a representation of a real space.

Objectives and Method of Research

This research has two objectives:

- study the Ecological Validity of a Computer Generated Model and a Real Scale Model in representing a real space; and

- compare the results of the two models.

As means to examine these problems an experiment was carried out using a Real-Scale Model and a Computer Generated Model of a real space. The space (Fig. 1) chosen was the living area of the basic apartment of a low-income housing project in Guatire, Estado Miranda.

Fig. 1 Real space.

Fig. 2a-b The *Real Scale Model* was done using quick assembly plastic building bricks and mock-up furniture.
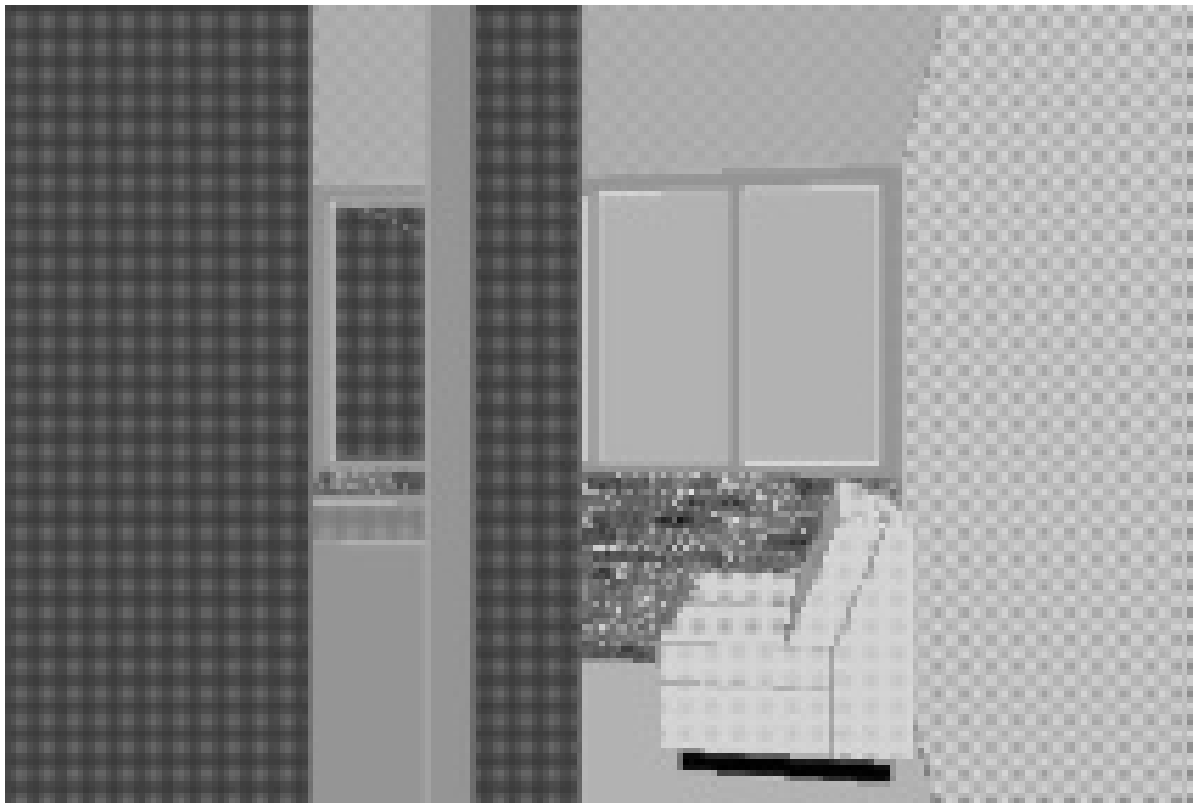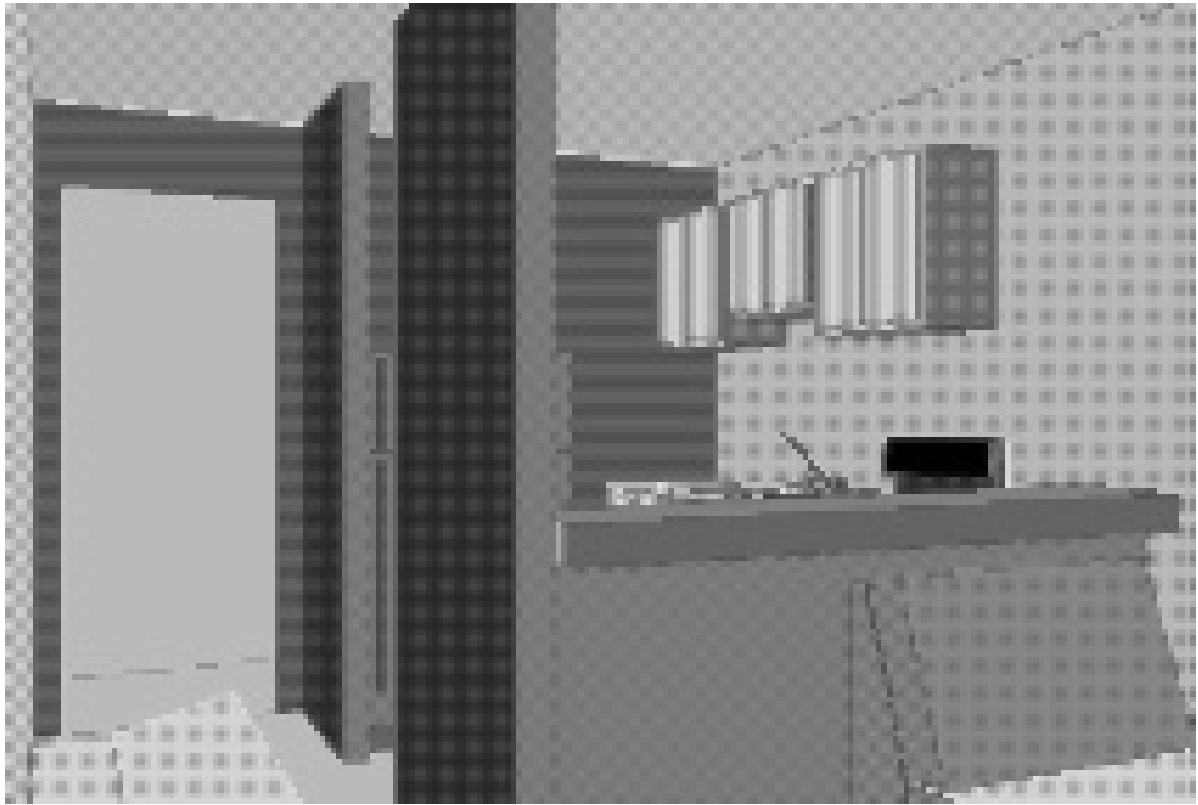
Fig. 3 The *Computer Generated Model* was realized using *Virtus Walkthrough.*

The real space and the two models of the space were evaluated using the Psychological Impressions Measuring Test (Fig. 4) developed by Luis La Scalea (1991). This test was designed to measure peoples psychological impressions produced by a space. It consists of a semantic differential formed by eleven pairs of opposing adjectives set on a scale of seven levels, that can be grouped in three factors:

- *Dimensional*: related to the form, size and pressure produced by the space;

- *Affective*: refers to emotions produced by the perception of the space;

- *Social*: related to values, beliefs and habits of subjects.

Open						Closed
Sad						Happy
Ordinary						Refined
Oppressive						Spacious
Pleasant						Unpleasant
Confusing						Clear
Elegant						Tasteless
Interesting						Boring
Oppressive						Spacious
Warm						Cold
Vulgar						Distinguished

Fig. 4 Psychological Impressions Measuring Test (IMIP).

From a basic population of randomly chosen senior students of the Faculty of Architecture of the Central University of Venezuela, three similar groups of 18 students were formed. Each group evaluated one of the models or the real space.

Results

The results of the evaluation of the Real Space were compared to those of the RSM and of the CGM using the Mann-Whitney U Test. This is a powerful non-parametric alternative to the test, that allows the researcher to examine if there is a significant difference between two independent samples. First, the results were related by pairs of adjectives and then they were grouped by factors. As a way to test the results, the estimated normal distribution of each sample grouped by factor was plotted and visually compared.

The results of the comparison by pairs of adjectives of the Real Space and the RSM (Table 1) showed no significant difference between all the adjectives

except one (sad/happy). On the other hand, the results of the real space and the GCM revealed that there are significant differences between almost half of the pairs of adjectives (sad/happy; oppressive/spacious; confusing/clear; interesting/boring and warm/cold) These results tend to indicate that the perception of the RSM is more similar to that of the real space than the perception of the CGM.

Pair of adjectives	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11
U	92.5	32.5	61.0	54.5	79.0	107.0	68.5	61.5	89.0	104.5	81.5
Distributions probably different	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 1 Results of U test between the Real Space and the Real Scale Model.

Pair of adjectives	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11
U	75.5	48.5	66.0	47.5	66.5	38.0	76.0	25.0	75.0	78.0	65.5
Distributions probably different	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO

Table 2 Results of U test between the RSM and the CGM.

The second level of analysis grouped the results of the evaluations by factors (table 3 and 4). This reveals that the perception of the RSM is similar to that of the real space only on the dimensional factor while the CGM is perceived alike in two factors: the dimensional and the social.

	Real Space/Real Scale		
	Dimensional	Affective	Social
U	68.5	41.0	50.5
Distributions probably different	NO	YES	YES

Table 3 Results of the U test between factors of the Real Space/Real Scale Model.

	Real Space/Computer Generated		
	Dimensional	Affective	Social
U	77.0	33.0	62.0
Distributions probably different	NO	YES	NO

Table 4 Results of the U test between factors of the RSM/CGM.

A final test was done by plotting the estimated normal distribution of the evaluations grouped by factors (fig. 4). The visual analysis of the graphics reveal that the curves produced by the models were similar but they do not match the one formed by the real space. This supposes that neither models reproduces exactly the evaluation of the real space. But, closer scrutiny shows that the curves correspond better in the dimensional factor, while there differences are more evident in the affective factor.
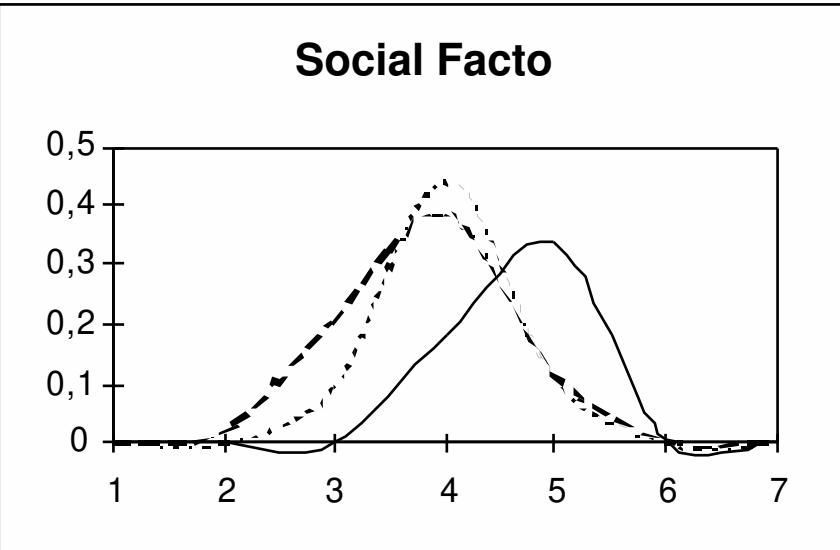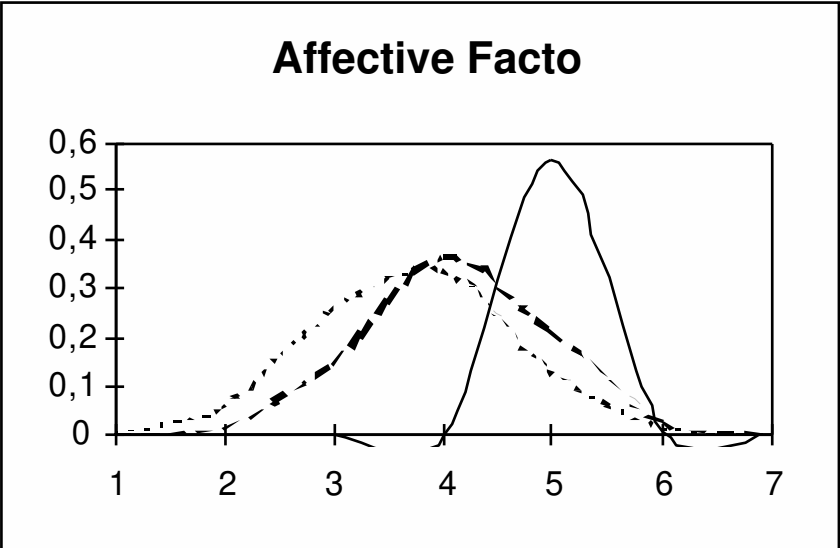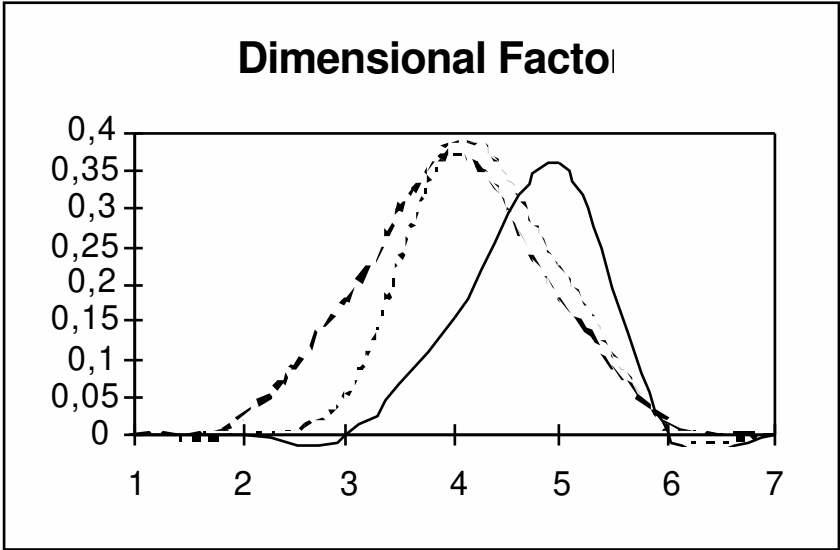
Fig. 5 Estimated Normal Distribution.

Conclusions

From the analysis of the results we can assume that the RSM and the CGM can be considered as ecologically valid, because with them the psychological impressions of people will be equivalent to that of a real space. Even though, on a general level, the perception of the RSM seems to be more similar to that of the Real Space than the one produced by the CGM. The analysis by factors shows that both models are similar to the real space on the dimensional factor but only the CGM can be considered as matching on the social factor. This difference between the two models tend to indicate that the amount of details rendered by them affect the way that they are perceived. The RSM allows very few modifications of variables considered important to recreate reality (color, texture, etc.) while the CGM is more flexible. This influences the amount of information that each model can afford, thus changing the social and affective perception of the space. The visual analysis of the estimated normal distribution of the evaluations grouped by factor confirm the idea that these models represent well the dimensions of a space but do not afford enough information as to be representative of its affective and social character. The RSM and the CGM, at there actual stage of development, will never replace real space, but with more knowledge of there advantages and limitations it will be possible to use them in an affective way as surrogates of real space or as a means of controlling variables when studying the built environment.

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III

THE NEXT GENERATION

The Next Generation of Architecture within Computer Science

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Abstract

Technical inventions and developments have resulted in advantages and disadvantages for the well-being and prosperity of mankind. Advanced computer technology has brought in a lot of improvements in different fields, but some disadvantages as well. The developments in the field of computer science have also an inevitable influence on architecture, therefore we have to deal with chances and problems of computer application in the building process. How did the computer science influence the architecture till now, and what is going to be the future of architecture with this ongoing developments of computer science? In which way will these developments affect the position and the responsibility of an architect? In this paper we will discuss these questions and present our "vision of the future".

Introduction

Information and Communication Technology (ICT) has a great influence on behavior and functioning of human beings and therefore, in a more wider sense, at mankind and society as well. The development of the advanced computer techniques and technologies has also an influence on architecture. Computers are in common use in architectural offices, till now mostly for drawing purposes. The developments in fields like building technology and material sciences offer a lot of new possibilities for architecture with respect to the use of new materials, the application of new construction techniques, the buildability of designs, etc.
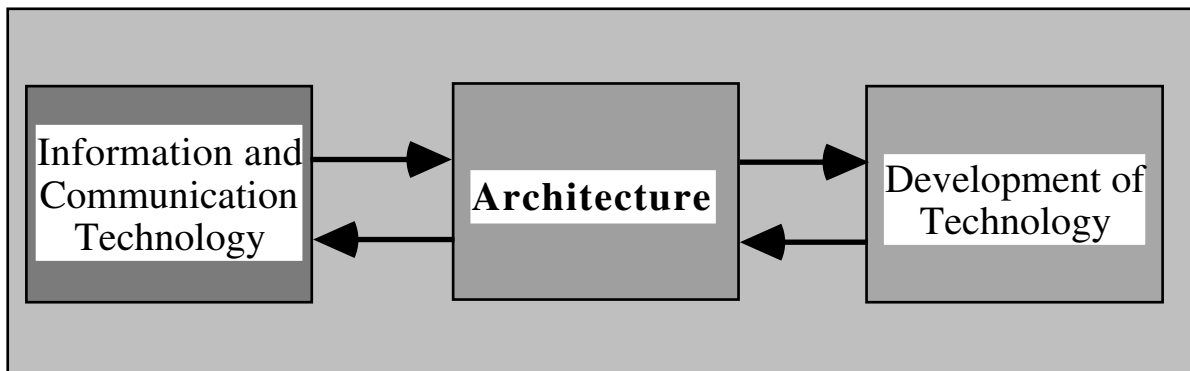

Fig. 1 The relation between architecture and technological developments.

These possibilities are applied in current architectural practice. Some architects go even further and initiate the development of new technologies. In this sense we can consider architecture a significant stimuli for future developments in these fields. Figure 1 illustrates this interaction between architecture and technological developments.

The subject that we decided to take into account is extremely broad and endless discussions could be held about it. Therefore we will try to concentrate more on the nearest future which is almost already knocking at our doors in search for the answers. At the beginning we will have a look at the development up to now.

The Way Ahead

The only way to look into the future is to look back into the past in order to be able to answer a lot of questions, such as:

- Why computer modeling?
- Why architecture in combination with computer science?
- Is computer science essential for researching human space forms?
- Is computer science essential to handle complications in the field of building technology?

The answers to these questions are for the next generation. Architecture is a mixture of art (emotion), materialization and technology taking into consideration the human behavior and welfare. Since architecture is a product with a great tradition there is more reason to look into the past. Think about what the Greeks have done in the field of architecture, like the Agora houses, etc. What has come into existence in the Middle-ages? For instance the Gothic-style with influence of the Arab's pattern grammars. What was the communication system? The people themselves? Do not forget the Renaissance, neither the revival in the sixties etc. To design in the past was a very handy work. When an architect, in the seventies, started to develop a building, it was popular to start with a pencil and a piece of paper and draw the first ideas. In principle that is the same as in the Stone Age when a person used a little stick and a sand surface. But in our time, the building itself has become much more complex, not only in its function and form, but also in its infrastructure, communication technology, security, etc.

The variety of solutions, to construct and materialize buildings, is enormous. What are the reasons? In the seventies human brains have worked out a new architectural philosophy:

> "A building is a part of the cosmos, That means that the inner space and the outer space are not in competition with each other but have to compensate each other."

That means that the construction of the outer walls had to be open and light. The first consequence was a de-materialization process in the field of architecture. That means, in "use less more material". The complexity grows! The next consequences were that buildings have "less more weights", but also the role of the advisers and consultants became more important and relevant. One of the reasons was, for example, an acoustic problem that arose because the sounds from the outside entered easily through the light-weight walls and the inner climate-control was in disorder. By using light-weight walls and large glass surfaces the heat "gets" into the interior. The consequence was the development of a design with a complete climate-system taking a lot of energy and consuming more space. In the past the mass of bricks was the solution for this kind of problems. By this kind of complexities the architect needs a lot of consultants and advisers. Even the local authority (town-development, building-controllers, etc.), in his own organization, is much more complex than several years ago. It is hardly possible to handle this complexity as a single architect. Therefore, to design a well-balanced building communication is one of the most important things. A possible solution can be found in the use of suited software systems supporting the architect during the design process. The consequence is that not only the technical problems are easy to be solved but there are also possibilities to research the human-space models on a 3D computer system. In the next chapter we will deal with these possibilities and summarise current research concerning the application of ICT in the field of architectural design.

Current Research

We generally consider architectural design as a process consisting of two main phases - conceptual design and materialization. Conceptual design includes a global design of forms and relations between different parts of the object to be designed. In the materialization step the forms are substituted by construction components and materials. A large variety of tasks has to be executed during the materialization phase. It includes dimensioning processes, determining the construction, materials and building details, considering building provisions, etc.

With respect to the importance we can state that materialization is the key issue in the architectural design process. Furthermore, it has above average importance for the whole building process. We have to consider these facts when discussing possibilities of computer support for architectural design.

It is common knowledge that a computer is very appropriate to check exact criteria and in the materialization phase data become more and more exact. So far materialization has been achieved through time-consuming procedure, according to traditional methods, which often fail the effectiveness and consistency and do not offer all the possibilities from which to select. The developments of methods by which three-dimensional materialization can be supported by means of computer science technology is largely unexplored territory. Therefore, it is quite logical that much effort is taken in current research projects and has to be taken in the future to achieve improvements for the materialization field. Current research in this field includes the following two important features:

- The development of design tools for the different materialization sub-processes;
- The integration of these tools into integrated design systems.

Both of them have to be taken into consideration to achieve fundamental advances. Generally, we assume a design methodology based on 3D representations for the whole design process despite some early steps as approached in [1]. Some examples for required design tools are:

- Tools for the generation and evaluation of design alternatives with respect to the selection of materials or constructions;
- Tools for the research of the spatial qualities of the design;
- Tools for the dimensioning processes;
- Databases for three-dimensional standard details including functions for the easy use of these details in design projects;
- Systems for the handling of building regulations and
- Decision support systems for the different kinds of materialization tasks providing knowledge of different specialities.

Besides the development of new tools there is also a need for improving the application environment of these tools. We have to avoid situations where limitations occur because of incompatible file formats and incompatible communication protocols or because of user interfaces that are not suited for the people working in the field of architectural design. This is the reason why

"integration" is a key feature. Instead of only developing design tools we also have to deal with their integration. We have to develop integrated software environments consisting of a framework and several design tools.

The software environment or framework realizes facilities for data and design management. New developed tools can be implemented according to these existing facilities avoiding the multiple implementation of generic functions. The integration of tools developed independently could be realised by using known tool coupling methods. With the services of the integrated environment, the developed tools and the integration of existing tools a system becomes available that supports the architect in a general way [2].

In this chapter we have shortly discussed possibilities offered by current information technology. We have made significant limitations by only taking into account the architectural design process and not the whole building process. Additionally, we have not looked into the future development of technology. In the next part we will overcome both limitations and extend our concerning field to the use of computer science technology in the whole building process.

Future Expectations

It is obvious that in every day life the Information and Communication Technology (ICT) has a great influence on behavior and functioning of human beings and therefore, in a more wider sense, on mankind and society as well. It is almost impossible to keep pace with the incredibly rapid developments in the field of computer science. Computers are becoming cheaper and increasingly powerful, and technically, they can now exchange data via fibre optics cables at a rate of 1 billion bits (1 Gigabit) per second. Internet makes the world smaller and smaller, bringing scientists in very close contact with each other. Networks enables them to communicate night and day.

Today these networks, combined with fast computers, make it possible to simply exchange graphic data (drawings, photographs, films, etc.). This used to be almost impossible because of the size of graphic computer files. Until a few years ago one of the largest architects' firms, SOM (Skidmore, Owings and Merrill) sent drawings from their London-based agency to their Chicago office by means of a courier service; now they use Internet. Now, researchers may execute simulations by remote control, for instance, or hold a conference by video with colleagues abroad. What further developments may be in store for our subject area in the near future? What is going to be the future of the architecture with this ongoing of computer science development?

Early developments of computer science in the field of architecture involved 2-dimensional applications, the computer is replaced by the drawing table and tools and subsequently the significance of the third dimension became manifest. Nowadays, however, people are already speaking of a fourth dimension, interpreting it as time or as dynamics. And what, for instance, would a fifth, sixth or X-dimension represent [3]? In future we will perhaps speak of the fifth dimension, comprising the tangible qualities of the building materials around us. And one day a sixth dimension might be created, when it will be possible to establish direct communication with computers, because direct exchange between the computer and the human brain has been realised. The designers ideas' can then be processed by the computer directly, and we will no longer be hampered by obstacles such as screen and keyboard. This is mere speculation, and seems to be far-fetched, but just take your minds back 50 years ago, when nobody could even imagine that today everybody could be walking in the streets with a wireless telephone. Till now, we were dealing with data processing and the conversion of this knowledge into a computer model, which means dealing with the material world, for which the tools of computer science are highly appropriate. But what will happen to the immaterial world? Can we "teach" computers these immaterial values?

Scientists are still busy putting up the human intelligence into a computer model and trying to develop systems which can imitate the human intelligence, just think of the developments of the neural networks. If we look at human intelligence; intelligence is the ability of a person to think or reason. Humans have native intelligence and can build or improve upon it. Machines can have only limited intelligence. The most important aspect is the wisdom of a human being. A wise person is learned and experienced. Wisdom also implies common sense and good judgement. Computers may have limited forms of intelligence, but only humans can have wisdom. Nowadays the research is going on to make bio-chips to imitate human brain. We are not saying that it is impossible but we have still doubts about it. Human beings nowadays cannot even make a human cell, they are only busy in the manipulation of a cell. There is still a long way to go. That's why we should not be afraid that the machines will take our place! The development of advanced computer techniques and technologies surely influences architecture and that is almost inevitable. It will influence the very near future, as well as, on a future that lies "far ahead" of our time. Some architects have already decided to run parallel with technology, because they have realised that if they would ignore these developments, the technological culture might just go on without them, and no one likes the feeling of being "deserted" and "left behind". In future the influence of ICT will be both in the conceptual phase of a design (the form aspect) and the materialization (the technical aspect).

Naturally the processing information itself will be different as well. The architects are already designing the unusual spaces and concepts by the influence of the ICT. At the moment a school project has started in Den Bosch (Holland) an open form and a totally different concept than a traditional school building.

In today's urban environment we became very dependent upon information. With computers connected to a network we all realise that the world is coming into our room and we hardly have to step out of that room in order to gain information. We really feel as a citizen of the world, being able to exchange and obtain information and knowledge within few seconds. The fact that it will not be necessary to leave home, means that perhaps in the future the need for the office buildings might diminish or even disappear, thus, by means of further developments of the ICT, people will work and spend more time in general in their own homes. Just having this development in mind we can imagine what consequences it could have on the behavior patterns within the society and on architecture of the future as well.

If we look at the basic needs of a human being like eating, drinking, sleeping and social contact with other people, we can say that most of these needs can be fulfilled in so called "working home environment", but the last aspect and the need to have direct social contact to people will still happen outside the home. This will remind us of earlier periods of architecture and the Greek agoras. In future the social spaces will gain in importance in daily life where people come together. History is repeating itself, with some changes, however.

In Japan the urban planners and the architects are busy to solve the problems of a high population-density in the cities and also the negative aspects of the contemporary cities for the environment. It is a fact that in the 19th century 3% of the world population were living in the cities whereas in the 20th century already 15% of the population live there. According to estimations in the coming century 3 of the 4 people in the world will live in the cities [4]. Japanese started to develop a project in Tokyo which is called "Sky City 1000". The architect of it is *Shizuo Harada*. The aim of the project is to build a huge cut cone form of few buildings which is 2004 meter high. Within the building everything is planned which we have had in the normal cities in horizontal form. This time it will have an vertical form. This brings also other technical problems with it such as the velocity of the transport lifts and the influence of it for human health or the temperature problem. Because in 2000 meter height the temperature is about 13 degree lower than on 0 height and the water boils at 95 degree Celsius.

Conclusions

The emergence of new technologies will affect our subject area; our way of living, our cities, our habits but this will create new challenges, new concepts, and new buildings in the 21st century. All in all, as architects and planners our responsibility will be to have both feet firmly on the ground, and to bear in mind that we are dealing with the well-being and the prosperity of mankind.

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Simulation for Analysis: Requirements from Architectural Design

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Abstract

Design analysis has been traditionally performed according to normative rule-based systems. Simulations where designs can be examined intuitively in full detail and at the same time by quantitative models are preferable, as they extend to issues inadequately covered by normative analyses such as dynamic aspects of design. Given the variability in the form of designs and in the possible users, testing prototypical designs by typical users is insufficient for arriving at globally acceptable new solutions. Instead, we should test each design individually in its own context. To this purpose we need a fusion of computational and analogue technologies for full scale simulation. By registering the actions of a large number of test persons in a full scale laboratory through motion capture we derive a sufficiently varied number of user profiles. These profiles subsequently drive virtual humans for testing computer simulations of the built environment with the precision, accuracy and reliability current design problems deserve.

Design, Analysis and Simulation

Design analysis and design theory are traditionally geared to generative approaches. The numerous analyses of the design process have resulted into a multiplicity of models which attempt to describe the steps a designer takes in the quest for a satisfactory solution. Most models also aspire to prescribe the optimal sequence of design actions. What they propagate is a form of orthopraxy (as opposed to the orthodoxy of formal systems such as the Classicism and the Modernism). Their underlying assumption is that if one follows the sequence of design stages prescribed in the model, they can arrive at a design that satisfies the programmatic requirements.

It is unfortunate that no such model to-date can match the intuitive performance and creativity of the human designer. Being based on metaphors and similes, most models do little beyond explain a few specific aspects of designing. Moreover, while they may improve the designer's awareness of their actions and decisions, they seldom lead to the development of new, sharper tools for higher effectiveness and reliability in the face of today's complex design problems. Perhaps the main reason for the scarcity of such tools lies in the relative lack of interest in the analysis of design products.

Historically such analysis has been subservient to synthesis. Long before terms such as functional analysis and programmatic analysis were invented, buildings and design decisions were being parsed towards an identification of their causes and effects. These were subsequently formalized into rules and stereotypical „good" solutions which served as the basis of most building regulations and design textbooks. Rules and stereotypes have mostly a proscriptive function. They attempt to offer design guidance by pointing out errors and inadequacies, i.e. what falls short of the established norms.

The proscriptive approach also underlies computational studies which focus on the analysis of designs using the same or similar rules transformed into expert or knowledge-based systems. In these a design is described in a piecemeal fashion which permits correlation of the relevant aspects or factors with the rules. The end product of the analysis is an acceptability test based on the matching to the constraints of the solution space. The added value of such systems lies in the provision of feedback which facilitates identification of possible failure causes.

Other computational studies rely on mathematical models for the measurement of projected values and patterns in a design. These have been applied mostly to environmental aspects and constitute a significant promise for improving the designer's instruments. However, computer systems which derive from such studies have long remained first-generation attempts, hampered by their reliance on models which are insufficient for projecting the behaviour and performance of a design with accuracy and precision [1].

Our working hypothesis is that design analysis is moving towards a new paradigm, based more on simulation than on abstractions derived from legal or professional rules and norms. Recent developments in areas such as scientific visualization offer advanced mathematical and computational tools for achieving high detail and exactness, as well as feedback for design guidance. The close correlation of photorealistic and analytical representations (figures 1 and 2) clarifies and demystifies the designer's insights and intuitions. Moreover, the combination of intuitive and quantitative evaluation offers a platform of effective and reliable communication with other engineers who contribute to the design of specific aspects.

The more abstract rule systems that underlie norms and regulations remain for the moment as a higher level of abstraction. Their utility in a multilevel analysis approach is twofold [2]. Firstly, they permit direct matching of a design to the legal minimal requirements. This is obviously an inescapable obligation of the designer. Secondly, the comparison of rule-based analysis with

Fig. 1 Photorealistic light simulation (Radiance image by A.M.J. Post, Delft).
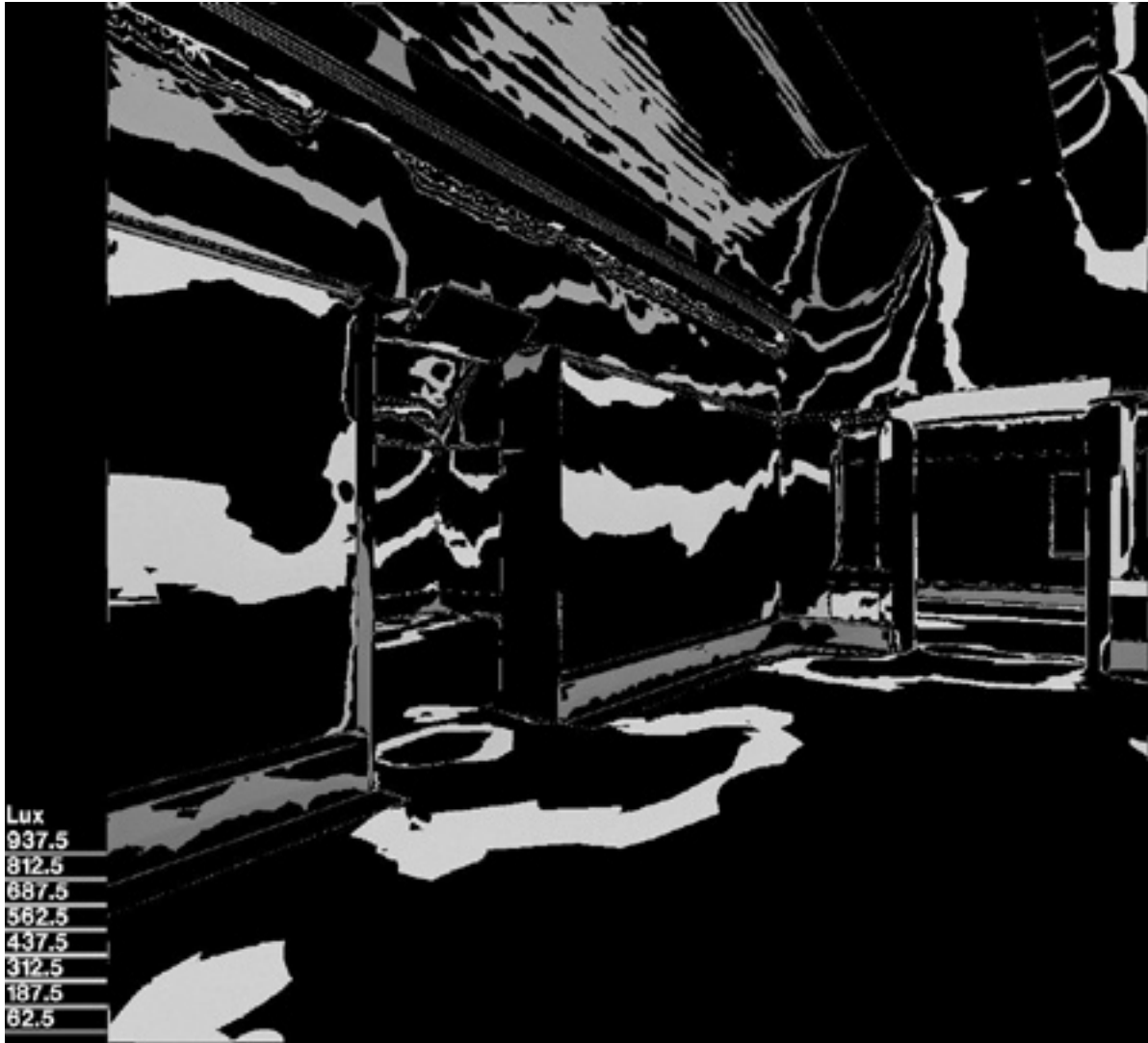
Fig. 2 Light simulation: intensity analysis in the space of figure 1 (by A.M.J. Post).

simulation points out the shortcomings of the former and hence the foci of more precise and accurate analysis. The reverse is more doubtful. The possibility that current rule systems can suggest ways of abstracting simulation results should be treated with caution so as to avoid deterministic searches for verification and validation of outdated, inadequate approaches. For example, acceptance of the underlying principles of fire escape in building codes and regulations provides a distorted picture of human behaviour (see figures 3 and 4) which can be corrected by subsequent analysis by simulation (figure 5) [2]. The same applies to human movement on stairs. The logic of Blondel's formula and of its epigoni fails to account for human flexibility and adaptability, as well as for failures in designs firmly based on such formulae [3, 4].
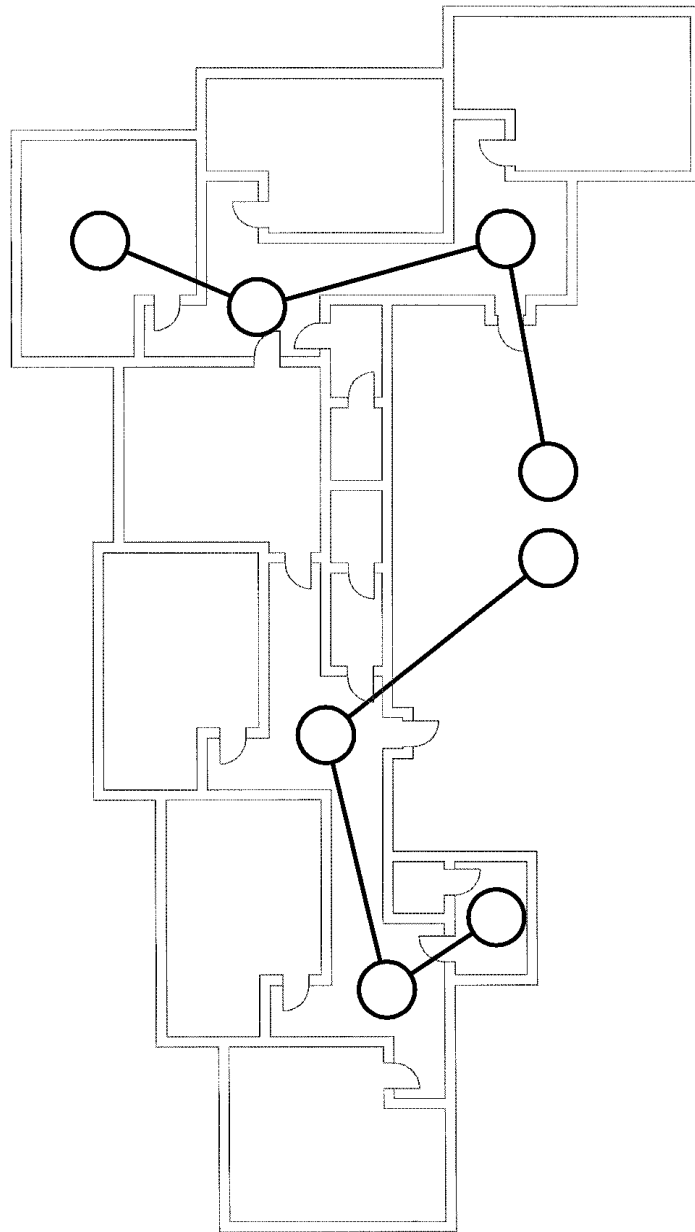

Fig. 3 Topological escape routes: normative analysis at a high level of abstraction.
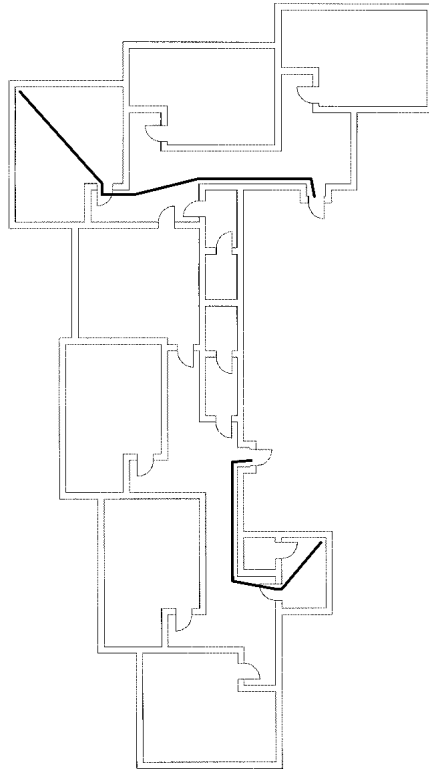
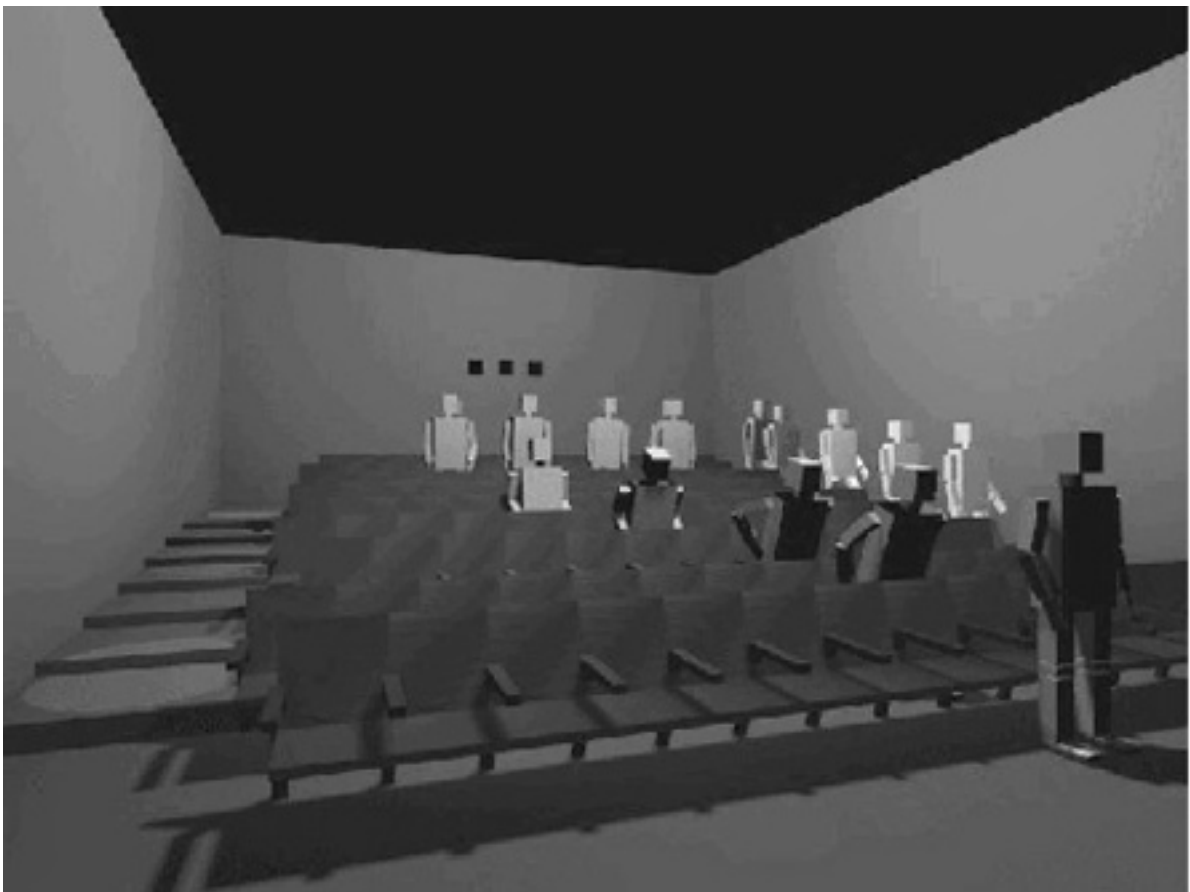Fig. 4 Geometric shortest routes corresponding to the patterns in figure 3.

Fig. 5 Simulation of human movement in fire escape (by H. van der Horst, Delft).

The Simulation of the Built Environment

Most simulation techniques provide amply for the detailed and realistic representation of the built environment. There is an abundance of modeling facilities which provide the basis for photorealistic visualization, often in relation to analytical representations, as in scientific visualization (figures 1 and 2). While these systems support intuitive evaluation and communication with other members of the design team, clients and prospective users, interaction with the models is hampered by the structure of the geometric models.

The main difficulty lies in the correspondence (or lack thereof) between mental design representations and the representations used in the simulation systems. The latter are generally derived from analogue implementation mechanisms used for the former [5]. As a result, the designer manipulates geometric objects such as lines and planes instead of interacting directly with design entities, such as the spaces of a building and the building elements that bound the spaces, let alone more abstract spatial or structural patterns [6]. It is possible that current approaches, based on redundant user input and data integrity and exchange, are ultimately incapable of supplying the desired combination of abstraction and specificity which characterizes the use of multiple partial representations connected to each other through recognition [7].

On the positive side, recent developments in rapid prototyping bridge the distance between analogue and digital simulations. Beyond its obvious industrial significance, this also supports a fuller examination and evaluation of design products. Instead of creating a virtual environment for presenting and analysing a new design, the designer can produce a full size mock-up of the design for the actual situation. This is of particular significance for the inclusion of human activities in the simulation.

The Simulation of the Users of the Built Environment

The complexity, variability and adaptability of human behaviour are good reasons for attempting to abstract human activities in the built environment into norms, constraints and rules of thumb. However, such abstractions fail miserably, even under conditions that may be considered normal but yet fall outside the scope of a norm or rule. For example, Blondel's formula for the geometry of stair dimensions (2 x riser + going = one step) cannot account for the intricacies of lower limb movement in stair ascent or descent or for the differences between the two [3]. It is therefore hardly surprising that, when applied to extreme conditions, such a formula produces unusable results.

Current simulation techniques have done much to produce realistic models of human movement in the computer. Still, even the most advanced models are not yet sufficiently detailed for an accurate projection of how a human interacts physically with the built environment. Moreover, most models refer to canonical sizes and conditions which may preclude the analysis of a design with users characterized by different mobility patterns, in particular children and the elderly.

Such problems can be directly alleviated by the use of motion capture to register the movements of test persons belonging to the different types of possible users of a design. The capture results can be linked to the basic models so as to derive a variety of profiles that represent the complete spectrum of kinesiologic possibilities, as well as sequences of actions that represent reactions to a certain event at a certain place. Such sequences can be an important addition to existing models of e.g. wayfinding behaviour at the onset of a fire escape route (figure 5).

Simulation, Registration and Analysis

The improvement of the built environment that can be achieved by the integration of better analyses in its design relies on the inventive and effective combination of existing technologies. In this combination the marriage of analogue and digital techniques plays an important role, as it facilitates the analysis of human activities in virtual environments.

The first problem that must be resolved concerns the derivation of information on the potential users of the built environment. Full scale analogue simulations can be used to register the behaviour of test persons that can be considered representative of the potential users. In the case of localized problems such as stair design and analysis, we can build a number of stairs with different forms and dimensions (typical and extreme sizes) and use motion capture to record the ascent and descent of real users of all ages, sizes and mobility categories. The recorded data are then collected in typical user profiles linked to models of human movement. Electronic publication of the profiles, e.g. on the Internet, makes possible their use for testing stair designs by means of simulations of virtual humans on the stairs. Mismatches between the movement expectations of the virtual humans and the stair form indicate possible fall dangers that deserve the designer's attention.

User profiles for larger scale problems, such as fire escape, can be derived in hybrid contexts, where full scale simulations (for test person movement) are complemented by virtual reality systems (for visual input). Obviously the complexity and specificity of such contexts means that they are purpose built,

each for a specific design. Generalizing the behavioral data recorded in these contexts is therefore a tougher proposition than in the localized problems. Nevertheless, the methodology of precedent and case based design can be applied to derive virtual human profiles from related design problems.

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                    │   geometric model    │
                    └──────────────────────┘
           ┌────────────────┐        ┌──────────────────┐
           │    computer    │        │ full scale model │
           │   simulation   │        └──────────────────┘
           └────────────────┘
                        ┌──────────────┐
                        │ registration │
                        └──────────────┘
           ┌────────────────┐        ┌──────────────────┐
           │    analysis     │◄───────│  virtual humans  │
           └────────────────┘        └──────────────────┘
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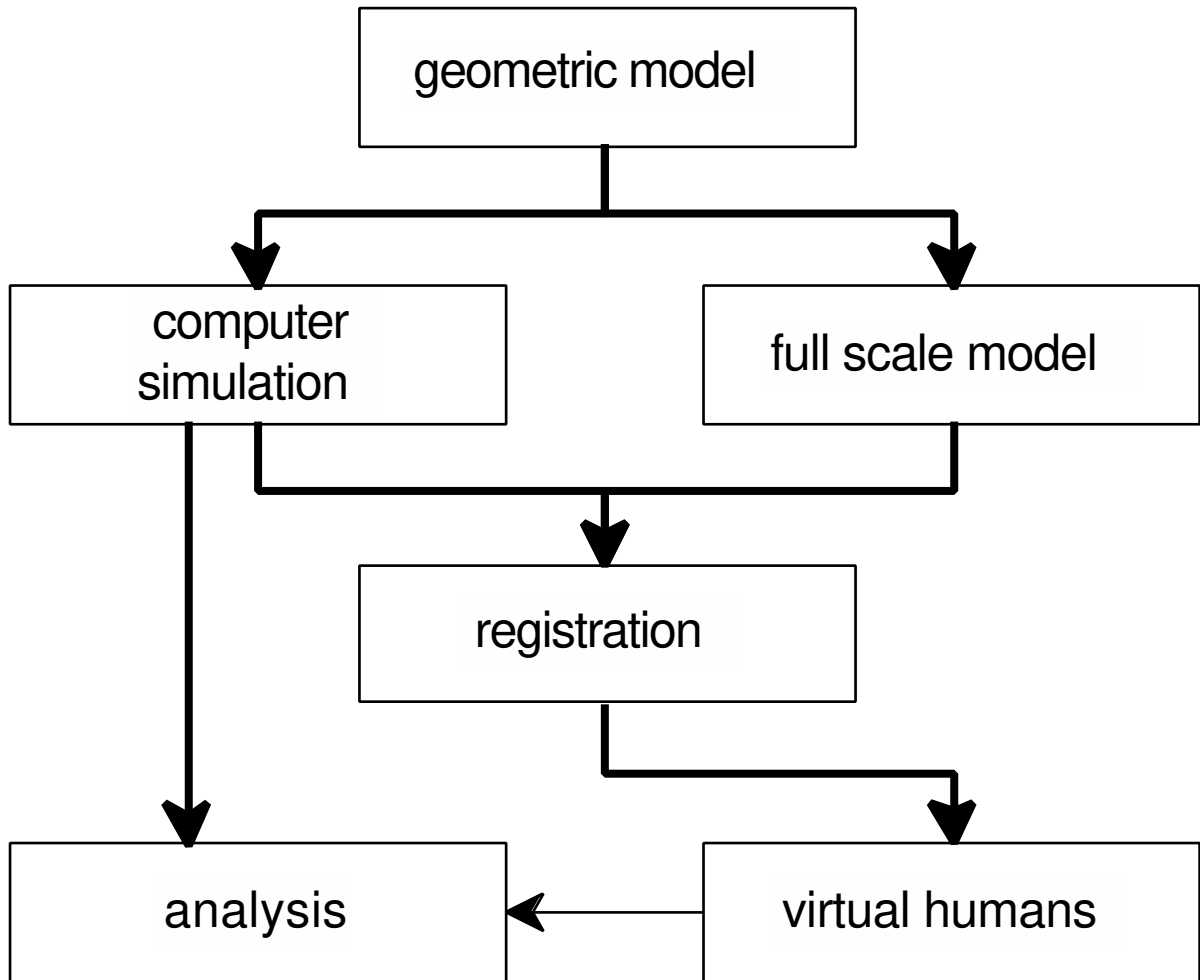
Fig. 6 Outline of the proposed approach.

The proposed approach asks for more than the combination of existing tools. The bringing together of different disciplines and specializations, from functional analysis and full scale modeling to computer science and kinesiology, presupposes a coherent framework of methods and techniques. It is questionable whether this framework can be derived from domain theories and general design or engineering methodology, even though these form a useful background to multidisciplinary communication. Concentration on specific problems which lend themselves to the approach may be preferable, as an exploration of the scope and constraints of the approach but also as an endeavour that leads to direct results: new design tools for practice.

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Spatial Navigation in Virtual Reality

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Abstract

For the past decade, we have carried out a number of participation projects using full-scale modeling as an aid for communication and design. We are currently participating in an interdisciplinary research project which aims to combine and compare various visualization methods and techniques, among others, full-scale modeling and virtual reality, in design processes with users.

In this paper, we will discuss virtual reality as a design tool in light of previous experience with full-scale modeling and literature on cognitive psychology. We describe a minor explorative study, which was carried out to elucidate the answers to several crucial questions: Is realism in movement a condition for the perception of space or can it be achieved while moving through walls, floors and so forth? Does velocity of movement and reduced visual field have an impact on the perception of space? Are landmarks vital clues for spatial navigation and how do we reproduce them in virtual environments? Can "daylight", color, material and texture facilitate navigation and are details, furnishings and people important objects of reference? How could contextual information clues, like views and surroundings, be added to facilitate orientation? Do we need our other senses to supplement the visual experience in virtual reality and what is the role of mental maps in spatial navigation?

Our Interest in Spatial Navigation

For several years, we have worked with participatory design using full-scale models as an aid for communication. The aim has almost exclusively been to model buildings from the inside and the interior design has partly been determined by the users, experience of the models. For the past year we have been part of an interdisciplinary research group, the aim of which is to compare different visualization techniques and design tools, among others, full-scale modeling and virtual reality, in design processes with lay-people. The tools will be used to visualize as well as to give shape and design to environments.

The VR-technique is fairly new and unfamiliar to us, but we have already noticed that experiencing space with such a tool differs from trials in full-scale models. An obvious difference is that individuals can relate their bodies to the space. When we compared users experiences of full-scale models to other

media, such as drawings and models on a 1:10 scale, in previous studies, we discovered that it is crucial to use your own body as a measure for, e.g. the size of a room.

In this paper, we discuss the differences between experiencing movement in virtually designed space and in real space. We base our reflections on former experience as well as on literature on spatial navigation in the domains of cognitive psychology and information technology. What should the requirements of virtual reality be when used as a design tool? What clues are needed to compensate for the reduction of reality when using this media?

Man and Space

Space is an essential concept to architects. Space can be both *social* and *physical*. Theories about social space have, as a result of the division of scientific disciplines, mainly been developed within the social sciences. Architects and art scientists have, however, developed theories about physical space. According to several authors (f.i. [9]), this is an unfortunate split since *action and space* can not be separated. Social space transforms physical space into a stage. It becomes the framework for *social interaction*, but it does not determine people's space of action. Without users or activities there is no point considering the concept of space. Despite this, our paper focuses on physical space. Virtual reality is not yet widely applied to social interaction and literature within the field deals mainly with the physical aspects.

Physical space has been defined in various ways. Some architectural researchers define it as the empty space created by the walls of a building. Others are convinced that physical space has to be experienced continuously, as a network of spaces, that can be experienced visually and by moving along the boundaries [10]. According to Zevi and others people, representations of space can be created with the assistance of different media, though the experience can only be transmitted by attending them. Only when we have access to space, walking it through, using ourselves as measures, we can truly understand it.

> "There is a physical and dynamic element in grasping and evoking the fourth dimension through one's own movement through space.(...)Whenever a complete experience of space is to be realised, we must be included, we must feel ourselves part and measures of the architectural organism." [10]

Primarily Zevi means that the proportions of a space are essential to the spatial experience. But other factors also have consequences for experience of space; for example light, shadow, color, texture, dominating horizontal and

vertical lines, the observers, expectations, the use etc. Further more, he emphasizes the difficulties in envisioning space. Even if, for example, scale-models are appropriate tools they offer neither enough information nor understanding about the relationship between buildings and measures of man.

> "Internal space, that space which cannot be completely represented in any form, which can be grasped and felt only through direct experience, is the protagonist of architecture."

> "The character of any architectural work is determined both in its internal space and in its external volume by the fundamental factor of scale, the relation between the dimensions of a building and the dimensions of man." [10]

In a study, Daniel Henry [4] tried to evaluate VR as a tool for architects. He alleges that VR fulfils the necessary criteria to give the user a correct perception of movement and space. VR creates the feeling of the body being in movement. The media gives a characteristic change of the visual field and a good apprehension of the spatial qualities, for example, limitations, connections and proportions of rooms as well as the quality and direction of light. Henry states that a strong motive for using VR in design is the impact movement through rooms has for experiencing them.

What is Spatial Navigation?

According to the Oxford English Dictionary navigation is *any of several methods of determining or planning ones position of course*. Tommy Gärling, a cognitive psychologist, defines spatial navigation as *a position in relation to a reference position* [3]. He distinguishes the body's orientation from, *the ability to maintain specific positions of different parts of the body in proportion to the ground* and spatial environmental orientation. The latter concerns *keeping the direction and position in comparison to the environment*.

In design work, spatial navigation also has the crucial dimension of experience from the point of view of content. In our field of research, navigation not only concerns finding the way from one place to another but is also expected to inspire creativity; altering and improving the observed environments. Therefore, the general definition of spatial navigation is insufficient. It is not only a matter of perceiving and learning a structure to create a mental map, but also, to appraise how the environment can be changed and adjusted to suit individual preferences and needs.

Navigational Aids for Representation

How then can spatial navigation be understood within our research field and how can spatial navigation in virtual environments be facilitated? What clues are used for navigation; have landmarks and mental maps the same significance when moving in virtual environments as in real environments and how are they created? How does the speed of movement and the visual field influence our experience? Does view, survey and visual contact with the immediate environment have an impact on orientation? Is our image of spatial connections shaped by realistic movements through buildings or can it also be obtained moving through walls and floors?

Light, shadows, color, material, texture and structure are fundamental to the experience of space and orientation in real environments. Details, interiors, furniture and individuals (the navigators and the people they relate on) provide further interesting reference objects. Can these also be used as navigational aids in virtual reality? There is a reason to believe that senses other than sight are important to the ability to orientate. Is it, for instance, likely that different kinds of sounds, such as footsteps, wind, running water, machines and traffic could facilitate navigation in virtual reality?

How can we attract the navigator's attention to the specific qualities of the environment and thus direct their movements? Should it be done as a dialogue by posing strategic questions about the environment? Or can sound, light and color be utilized to call attention? In a postgraduate course in *Human Computer Interaction*, we had the opportunity to examine some aspects of spatial navigation in virtual reality in practice. As a part of an interdisciplinary group of six people, we designed and carried out a minor test.

The Lay-out of the Test

The task was to create a tool for people looking for apartments and for an estate agent selling and renting flats that have not yet been built. Lay-people should be able to navigate in the entire building, enter the flat virtually and move around in it. They should easily obtain a mental map of the lay-out. They should also get a view of the surroundings and have control over the interior, changing wall-paper, cupboards etc. Mobile furniture should be available allowing for individual choice. The test consisted of four steps, in each of which the flat was presented in different ways. The main objective was to investigate how a map affects the ability to navigate within a flat that is unfamiliar. Two of the presentations were computerized, the third method was a video-tape of the flat built in the full-scale laboratory and the last was the full-scale model itself.

We selected five people, two female and three male to be our subjects; three architects, one psychologist and one secretary, implying that only two of the subjects were lay-people.

The *first step* was shown on a computer screen. Views of the rooms were displayed by clicking on descriptive buttons which were grouped by room. A movement history was recorded and displayed. The subjects could, thus, check where they had been and in what order they had visited the different rooms. The *second step* was the video recorded walk-through of the full-scale model of the flat. The *third step* again showed the flat on a computer screen. This time, a map was added, and the subjects could navigate by clicking on arrows in the map, indicating in which directions the picture was taken. Likewise, the movements were historically recorded. The *fourth and last visualization* was a real walk-through in the full-scale model. The subjects were guided through the ground-floor of the two storey building and their remarks were noted.
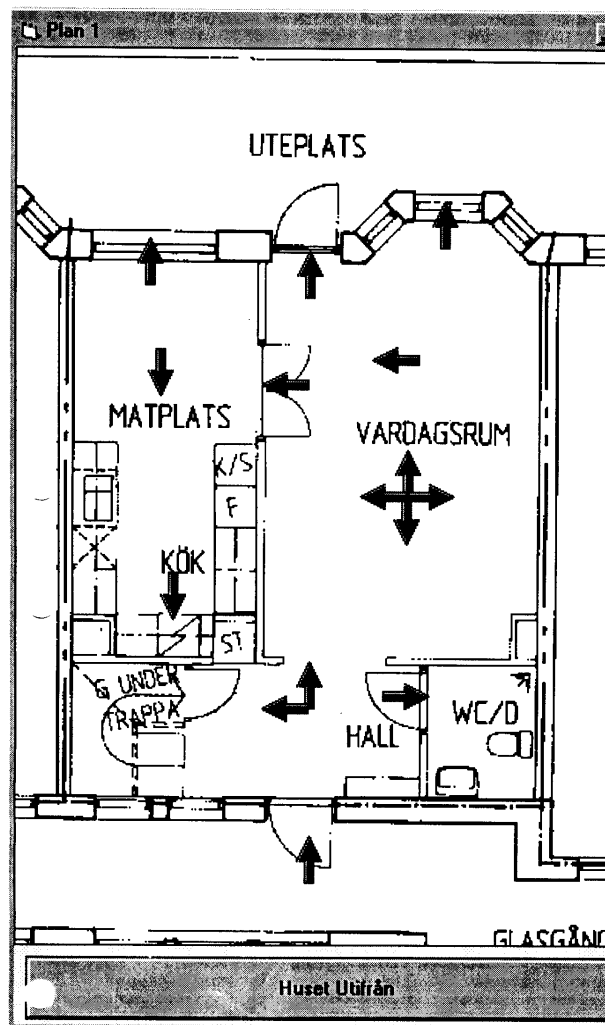

Fig. 1 Plan-drawing with arrows at the third step.

After each step, the subjects completed a questionnaire which asked what kind of supplementary information (text, map, animated pictures, sound) they required. They were also asked to rate how well they could interact with the test-version and orientate themselves using the different tools. After completing each of the questionnaires associated with the first and second steps, the subjects were requested to sketch the flat they had visited. They were also asked to compare the quality of navigation using the different media in all four tests, in particular, whether the map improved orientation.

The Results

Observation-time was limited. The subjects had to break their navigation tour after five minutes. The video-tape lasted about four minutes and could not be rerun. None of the test-systems were regarded as particularly interactive in the way they were used and presented. To increase interaction it should be possible to replay the video back and forth. The plan-drawing combined with photos, where the subjects could click in any order, was regarded as the most interactive navigation tool in this study. The plan-drawing was a big contribution in this respect.

The Flat Presented in Photos

The subjects were allowed to view the pictures for five minutes and some of them used all that time. They commented that a map would prove useful but found that the text added to the photos contained the most important information. Sound and animated pictures were not regarded as important.

There were some critical comments about the test-system, that is, the lack of pictures and the inconsistency in color and brightness. This made it difficult to consider them as a whole. Another deficiency was the lack of correspondence between photos and arrows. The historical review was very seldom used. On the other hand the system invited the subjects to push the buttons in their displayed order.

The system was not conducive to navigation. This was confirmed by the subjects, drawings. The two women were not able to understand the lay-out of the flat. The three men made a complete lay-out, even if is was not correct in all concerns. They had the correct interpretation of the relationship between kitchen and living-room and two of them also perceived the bay window. The site of the stairs and the bathroom were, however, difficult to interpret.
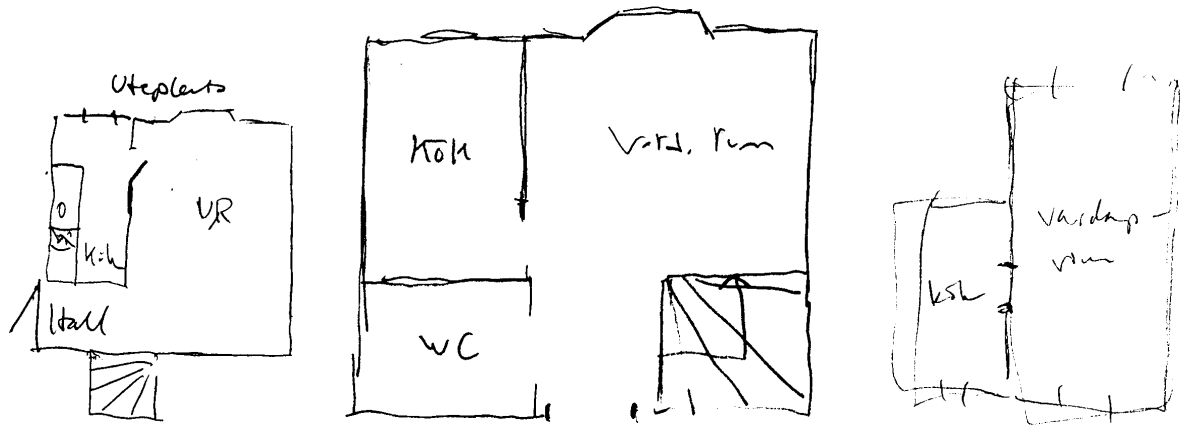
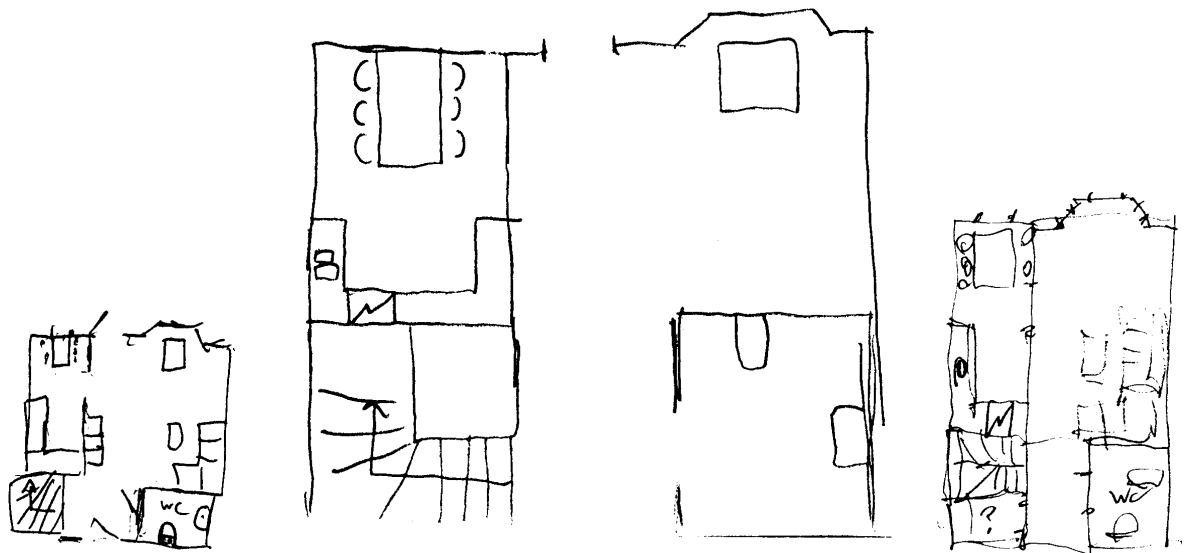Fig. 2 The first sketches made by the three male subjects.

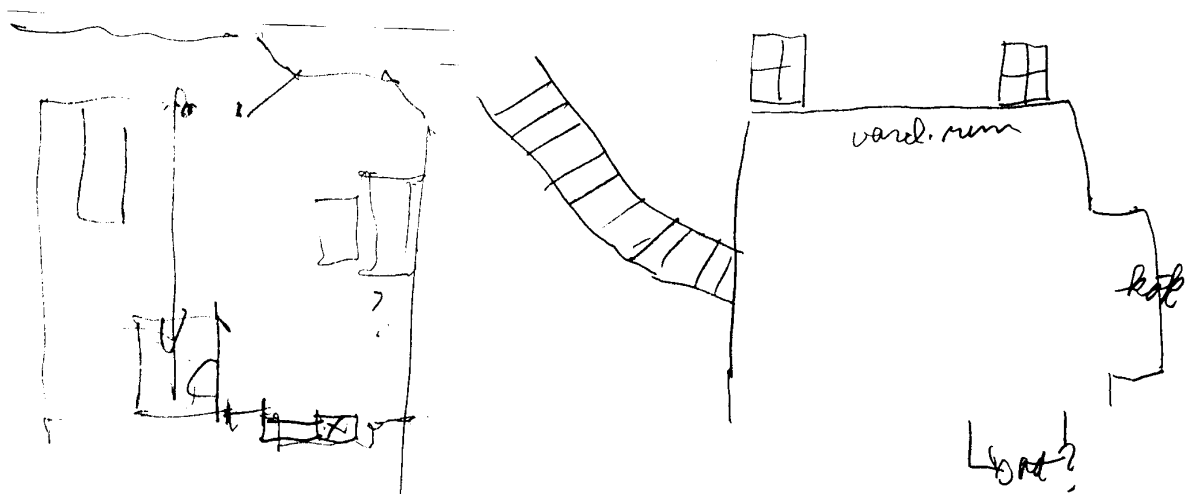Fig. 3 The second sketches made by the three male subjects.

Fig. 4 Sketches made by the two female subjects after the second step.

The Video Recorded Full-scale Model Walk-through

No sound was added to the video-tape and all subjects found this important supplementary information to be lacking. Including a written text would be fairly insignificant. Not all of the subjects were convinced that a map should be added to the video although most of them thought it would be helpful. The video seemed to give a good orientation of the flat. The two female subjects could now draw an incomplete plan-drawing, though their sketches did not correspond well with their earlier photo based ones. The male subjects attained a more congruent picture and modified their former plans, supplementing them with fittings and furniture. The view in the laboratory was confusing, as, for example, one could see a part of the laboratory hall through the entrance-door of the flat. Outside the model's outer wall, the laboratory's glassed wall could also be seen. This was perceived as a windowed passage belonging to the full-scale model. The video movements were sometimes too rapid.

Flat-show with Photos Added with a Map

When the photos from the first test (only photos) were combined with a floor-plan and presented to the subjects, the text grew in importance while sound appeared to be even less important than before. The plan-drawing offers a contextual understanding, which was appreciated. At this stage the subjects did not think that the video-film could add further important information. The plan-drawing facilitated orientation particularly for the male subjects. Their perception was similar to those acquired during the former tests. The plan-drawing was regarded as essential by all the subjects.

The Actual Walk-through in the Full-scale Modeled Flat

When the subjects finally "visited" the flat in the full-scale model, they were already quite acquainted with it, since they knew the lay-out. Though the dimensions did not correspond to their expectations. The video-film made the large space look larger - the living-room and the kitchen gave a deeper impression whereas smaller spaces, like the hall were unexpectedly larger in reality.

Some Interesting Findings

Four of the five subjects had the opinion that the flat that was presented in a plan-drawing supplemented with the photos gave the most realistic impression. One of the laypeople disagreed and regarded the video-film as the best presentation-media. The subjects were very critical about the quality of the photos. They thought they ought to be more consistent in brightness and color

to be interpreted as the same flat. The video of the full-scale model also confused the subjects, as it was not obvious what belonged to the flat and what belonged to the laboratory environment.

It was only on the video-showing, that sound was found to be missing. The echo (lingering note) for example, would be a useful source of information for the room size. The subjects used the bay window as a navigation landmark. It proved to be a useful reference point. As the subjects knew they were being introduced to the same flat in all the media they collected data from each step. The experimental design was thus thought to inhibit its educational value, however this carry-on effect could not easily be avoided.

Different Perspectives on Spatial Navigation

Different approaches to spatial navigation are presented in the literature. In the information technology field, the concept is used to explain orientation in hypertext. Spatial metaphors such as the city and streets are used to increase understanding of its structure.

Holmlid [5] discusses the suitability of using the navigation concept to interpret accessibility and path-finding on the Internet. He suggests that navigation in a hypertext structure like the Internet, is determined by the media and its mechanisms. Since the present media are built on links and nodes, there are insufficient qualities for it to be defined as navigation. He questions Diebergers use of spatial metaphors and the term navigation in the connection with hypertexts, since "every move along a line is to move an artificial distance in a spatial description".

This way of using the concept of spatial navigation does not refer to real, physical environments and is therefore of less interest to our topic. However the descriptions of spatial orientation in the literature of cognitive psychology are of more interest. Gärling [3] has, amongst others, been investigating people's navigation underground. He suggests that spatial orientation in real environments depends on their cycle perspective, their ability to master an environment, their motive for movement and how the environment is organized.

On the basis of this discussion, we would like to pick up some threads that partly encapsulates spatial environmental orientation with the focus on the virtual objects and tools that represent them as well as body orientation, here including the individual's subjective experience.

Physical Environments and Spatial Navigation

Recognizable landmarks and specific clues and reference systems, seem to have some influence on people's ability to orientate themselves [3, 7]. The environment's expressiveness is also important to orientation; differentiation of the landmarks, shape and color increases the likelihood of finding them. We have also experienced this in the full-scale laboratory, where the building system includes only white fittings. When the models are watched and estimated through video-films the lack of clues becomes apparent.

Visual accessibility is also essential to spatial orientation, for example by providing references by views through windows! This possibility is, for example, entirely missing in underground environments. These environments are furthermore rather poor and undifferentiated [3]. Therefore orientation in this type of space demands guides and posts (arrows, text information etc.) as well as simple systems for transportation and maps. The question is whether this is also needed in constructed environments like, for example, virtual computer environments.

The Significance of Maps for Spatial Navigation

The drawing-plan gives an overview of the whole building and it has therefore considerable significance as a tool for representing architecture. This merit was already pointed out by Zevi in the 50's [10]. The equivalent function of the map is also confirmed by other researchers. The main demand is that it can easily be translated into the real environment [3]. However it is not clearly stated what this means.

Libens [6] has established that even young children delight in using a map to understand and explore an environment before they reach it. This strengthens the map's significance for navigation. In our own study on navigation we also noticed that the use of maps is crucial. Henry [4] had the same experience. He established the importance of plan-drawings as additional information in spatial orientation when lay-people manipulate spatial environments in virtual tools for architectural purposes. In Henry's opinion it facilitates the users, revision and updating of their own cognitive maps of space.

"Mental Maps"

People's emblem and imagination of the environment seems to mean a lot to their ability to navigate in virtual environments. Cognitive or mental maps are recreated for every place explored in computer navigation and navigation models [11]. They can also be created (or rather recreated - a chicken and egg situation) as the cognitive map for a certain place begins with a generic

scheme based on the type of place which, in turn is based on both topological and descriptive knowledge.

According to Zimring, people, at least partly, seem to make their spatial choices based on general topological knowledge of a building, organization e.g. he uses the hotel-building. The cognitive map for a particular hotel is based on the general image, a scheme of "a hotel". The scheme announces the type of building and the spatial relationships one can expect. The investigation of the specific object, the particular hotel, results in a more specific mental map replacing the original schema of the hotel. Knowledge in building categories makes it easier to recognize places and to orientate in unknown buildings. It facilitates first-time visitors in finding their way around a building.

In his empirical research involving lay-people, Henry [4] has reflected on their difficulties in creating a cognitive map of the spaces they are exposed to in VR-environments. He claims that lack of kinesthetic feedback [13] might have an impact on the experience of harmony with the vision of movement. The movement dimension is, in other words, an interesting and perhaps important aspect of spatial experience, that has to be added to artificial environments.

Landmarks as Clues

It can be difficult to navigate in an unfamiliar environment despite it being interpreted by previous knowledge about other, similar environments. But what happens when we are supposed to orientate in environments that we have no comprehension for? What clues are needed to make the personal representation, our image, complete and to make the user able to navigate in the environment and to design it?

When we describe orientation in a city, the word "landmark" is often used. Kevin Lynch, who introduced the term in his book *The Image of the City* [7], means that landmarks, in this case mostly connected with buildings, are characterized by their uniqueness or differences from their surroundings. They are easier to visualize if they have a distinct shape. The shape in contrast to the background also seems to be an important criteria. Lynch distinguishes between two kinds of landmarks - the ones which are visible at a distance from different places and the ones that appear locally and diverge from their context. The former are mostly used by strangers in cities. The number of elements that will be perceived as landmarks depends on how well the observer knows the environment as well as the characteristics of the elements. Sound and smell can sometimes reinforce the meaning of visual landmarks

but they can not replace them. People do not entirely navigate with the assistance of landmarks but also relate to other associated objects that help to announce, for example, distance to the landmarks. The impact of texture and other tricks to deceive the eye into making perspective interpretations is further something that is used on theater stages.

According to Gärling, children relate things in their surroundings to their own bodies whereas adults use landmarks and reference systems, for example the walls of a room. The reference systems are not general but vary with the place. To be able to orientate, some adults memorize the way while others rely on the reference system.

The psychologists M. Tlauka and P. Wilson [8] state that the use of landmarks is one of several strategies people can use for navigation. When using landmarks, other equivalent strategies are suppressed. They have investigated the way in which people learn to navigate in computer simulated large-scale environments. Tlauka and Wilson define landmarks as distinctive spatial features that, by virtue of their shape, color, semantic value etc. have the potential to help individuals to orientate and find the way around an environment. They have found that both adults and children (compare with Gärling) use landmarks for navigation in unfamiliar environments. There is, however, no connection between landmarks and ability to orient.

According to Zimring [11] there is evidence that navigation is directed by memories of buildings, structures that have been experienced before. In his studies he found that people have the ability to predict the placement of important symbols in buildings they have never visited. When for example a high-rise office building is shown to them as a photo of a façade they can in most cases draw a simple plan-sketch showing the location of elevators and staircases. It appears as if location follows certain rules and many people can even describe where telephones and rest-rooms are located. People joining Zimrings investigations tended for example to organize buildings symmetrically and to locate elevators in the center. Also if people are not able to view a photo of a building but are presented with a concept, for example "office in high-rise building" or "a warehouse" most people seem to be able to make similar determinations.

To sum up, landmarks seem to have significance for people's ability to orientate themselves in familiar and unfamiliar environments. This also seems to include virtual environments, as we have experienced from our own pilot study.

The Subjective Dimension

Navigation is not only a matter of finding one's way. The aspect of experience from the architectural point of view is equally important! According to Zevi [10], all kinds of presentation tools have their deficiencies but together they offer a superior representation of architecture in comparison to what they would do separately. However, he considers that representations could only be used to visualize architectural space. The experience is far more complex and can not be fully reproduced. It is individual but at the same time dependant on the representations the subject is confronted with. A rich VR presentation can probably conjure up a more rich and dense image of the environment. A rich representation can probably also better hit the mark, as different individuals integrate different kinds of information in their cognitive system.

The significance of dimension is crucial for spatial experience. Therefore it is particularly important to represent them in a justifiable way. Henry [4] has stated that both horizontal and vertical dimensions as well as distance are experienced to be shorter in simulated environments. He has learnt that experienced distances are, to a greater extent, underestimated in the virtual environment than in monoscopic and stereoscopic "walk-through" representations. One of his own proposals to solve this is to include many, well known scale-elements in the model. This type of correction can only be used as a tool for control but not as a design-tool, as it hardly contributes to a fair experience of the VR-environment. The prerequisite to be able to estimate a rooms, quality is, also according to Henry, to be able to experience what it is like to be in it. In his studies he experienced that a wide visual field has a big impact on people's perception of different kinds of projections. This should therefore be taken into consideration when different visualization techniques are to be chosen. One solution is to increase the visual field of the display, he argues. Another is to use retroprojection, an immense screen with projection from behind.

The media also have an impact on rapidity of growth of the mental picture. Learning is an important element affecting navigation in virtual environments. Amongst others, Gärling is concerned about the ability to familiarize oneself with an environment. It is harder to become familiar in environments with poor spatial orientation. Gärling considers navigation as a way to learn:

- the route between defined places;

- the route-network and

- spatial relations (distances and directions) between different parts.

The Relationship Between the Body's Movement and Navigation

In experiencing the real world and full-scale models, movement adds an additional dimension that is separated from the media but close to the navigation system. In Henry's [4] test the subjects were particularly troubled with the movement metaphor in a virtual walk-through. The visual information was poorly equated with the few physical signals that were generated by the walk.

Sighted people that are constantly exposed to perspective transformations develop a sense of their own body's relationship to the environment. The effect of sight on navigation has also been investigated by Reiser, Guth and Hill [6]. They studied sighted and blind people's ability to link different parts of a room to each other. Due to their results, cognition seems primarily to rest on visual experience.

How is this experience used for spatial navigation in VR-environments? One can suppose that perspective consistency is, in some way, significant to how environments are experienced and to the manner of orientation within them and rendering of them. This was also implied in our pilot-study. The subjects, estimation of the flat's spatial dimensions diverged a great deal when it was experienced via video-recording as compared to a full-scale model. The physical model was experienced to be extremely small compared to the virtual one.

Individual Differences and Socio-emotional Factors

As some aspects of navigation are primarily linked to the VR rendering tool and others are linked to the human dimension, the personality [3] is yet an additional dimension, directing the experience of the environment. Liben refers to Golbeck for example, who compared subjects, ability to recall furnishing and executing their own drawing with the same subjects, competence to categorize and point out the connection.

Gärling stresses that some individual differences are related to development and age. He stipulates that, for example, children relate things in their surrounding to their own body. But according to Liben [6] studies reveal that blind children tend to achieve a fairly adequate inner representation of an environment by reading "tactile" maps.

There are also gender differences in the way human-beings interpret spatial presentations. Men, regarded as a group, perform better in evaluating spatial measures than women [6]. Our own results also indicated a certain gender difference in subjects, competence to interpret virtual worlds.

When it comes to children, Liben [6] has verified that the test environments greatly affect their performance. They are influenced by the unsafe situation created by the laboratory environment. By first making the children acquainted with the test environment, this can, to a large extent be avoided. The conditions for elderly people are the same. Furthermore, there is an important relationship between socio-emotional factors and environmental cognition.

VR is a peculiar technique for representation, that might demand certain assimilation efforts to both adults and children. At the very least, this concerns the technical equipment, that one has to adapt to and handle. Henry, for example, discusses the design of the head-mounted display-helmets. The ones used in his own experiments were designed for men. Participating women found that the helmets did not fit their head shape, thus interfering with their experience.

Summary

Our viewpoint of virtual reality as a design tool bears the stamp of our experience from full-scale modeling and has immensely directed our reading. Additionally, being a tool for design, the full-scale model is a communication tool for users, who lack professional knowledge within the field of design. Participative design must make the users aware of their ideas and how to change and adapt environments to their individual assessments and needs. Used as a design tool in participative design, VR has to act as an intermediary between adequate representations of spatial qualities - spatial boundaries and proportions, amount and flow of light and inter-relation of room. Experiencing space is a crucial complement to the analysis work where, amongst other things, measuring and rational arguments are involved. It has to be related to the corresponding real space and to the activities within it. In this paper our intention was to discuss the difference between movement in virtual space created in VR and movement in real, physical space. One of our questions was: what demands should be put on VR as a design tool?

The physical space is a continuous network of spaces and the tool has to mediate the feeling of movement. Researchers who have investigated the effect of the body's interaction with virtual environments have found that, for example, kinesthetic feed back is important. Can deficiency of certain sensory impressions be compensated by empowering others, like blind people develop their audible sensitivity? Could it be stated that the ability to interpret develops over time in a way comparable to the process of learning? Or is the interplay between the senses essential for re-establishing the virtual world with the real one?

To operate as a general tool, VR should be easy to manipulate so that lay-people can master it as well. It also has to be adjusted to the diverse personalities of the individual's and the interface has to be designed to be adaptable to individual body measures. It is also valuable that VR is made mobile so that it can be placed in familiar environments to give a sense of safety to its users. A consequence of this might, however, be that the user sticks with the solutions and proposals that can be achieved within this environment.

Concerning the significance of navigation clues in VR-worlds, the available literature is unambiguous. Clues like landmarks are easier to find if their shape is distinct and if their color is differentiated. The contrast between figure (shape?) and background is crucial. It may not be possible to make landmarks in VR visible from several spots but it will be possible to make them diverge from their context. As landmarks, associated with sounds and smells, stand out with greater clarity, these attributes ought to be additional clues in VR.

References like a rooms, walls or views through windows play an important part to spatial orientation in the real environment. If there is no possibility to create reference systems, there is a need for guides of different kinds; arrows, written information etc. By adding scales and reference-objects to the VR-environments and offering a wide visual field, the estimation of spatial measures in VR-environments can be facilitated.

Navigation manner is partly directed by memories from earlier, experienced building structures. The tool thus ought to conjure up this kind of visual picture and to work associatively. Photos of buildings as well as merely written terms mediate emblems of the building type and ought to also be useful in VR. Simple navigation systems and maps/plan-drawings, that can easily be translated into the real environment, facilitate orientation. The plan-drawing gives an overview of the entire building and helps the users to revise and update their cognitive maps of space in VR.

Our full-scale models are, to a certain extent, self-instructive, as lay-people easily learn to handle the media/building system. In the full-scale environment, we as architects are also to a certain degree the users, "clues" by interacting with them in a constant dialogue. VR has probably still better qualifications to operate self-instructively, since clues can be programmed for different purposes. The need to increase the amount of information and clues in order to direct and focus, is however in opposition to the goal of giving a dense and informative picture full of nuances. To create a tool that offers clues and at the same time does not direct the possibility of shaping new environments freely, is a difficult balancing act but also a big challenge.

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[12] Also other forms of "spinal learning" could be discussed.

Constructing the Amorphous

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Abstract

"Constructing the Amorphous" entails the ongoing research into a concept which aims to develop a new understanding for Art, Design and Architecture. Rigid, reductivist and confrontational methods based on static geometry, prejudice and competition are to be replaced by dynamic, interdisciplinary and integrative models. In my current art practice I computer simulate existing architectural spaces whose interior I redesign into sculpted environments, based on creative irregularity, rather than idealised geometry. These computer simulated "soft" environments are realised on an architectural scale as temporary installations. The rationale for sculpted environments, as well as the explanation of how to build such full-scale models, is exemplified using the Darren Knight Gallery project. The benefits of virtual representations versus an approximated full-scale model are discussed, assessing both cost and equipment implications. Comparisons are drawn with current rectilinear full-scale modeling techniques, utilizing bricks, blocks and panels. The research project "Constructing the Amorphous" is conceived as an interdisciplinary journey through different academic domains and aims to branch out and broaden horizons rather than reducing its investigations into a more and more specialized area. Therefore this paper refuses to end with a singular conclusion.
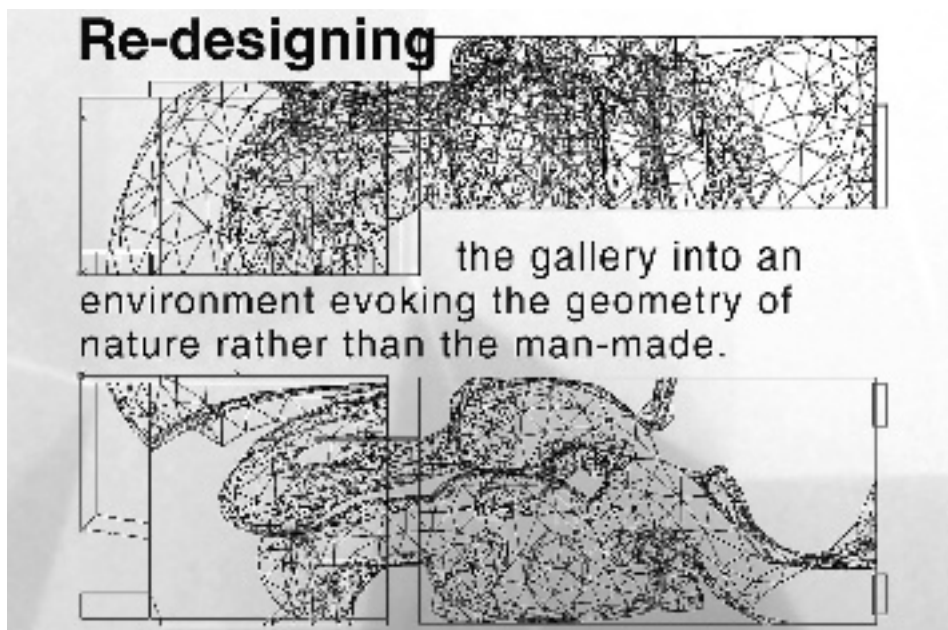
Fig. 1 Plan (bottom) and elevation (top) of re-designed gallery.

The Darren Knight Gallery Project

The entire project entails a number of interrelated works:

1. Measurement and computer simulation of the actual gallery;

2. The re-designing of the gallery into an environment evoking the geometry of nature rather than the man-made;

3. Production of high quality, computer generated visual material such as dye-sublimation prints, slides and broadcast quality videos of walk-throughs;

4. The building of the actual "soft" environment from corrugated cardboard as a temporary full-scale model;

5. Documentation of the project on the World Wide Web through HTML and VRML and

6. Documentation of the installed environment and viewer's perception of it through text, slides and video.

For the purpose of this conference I would like to briefly elaborate on points 2 and 4 - firstly why sculpted environments? - and secondly the actual building of the full-scale model.

Fig. 2 Why sculpted environments?

The reasons for wanting to create "soft" or highly curved environments are manifold. First of all I believe in the theory that the environment we grow up in plays an important role in the development of our overall awareness. It is not hard to imagine that someone who grew up in the tent of a nomad family would have a fundamentally different conception of the natural environment, leading to a different world view. I am also convinced that there is a correlation between our built environment with its flat, rigid and reductivist geometry and the tendency in people to hold on to outdated thinking patterns with respect to society for example. Our home - unsere eigenen vier Wände - that is where everything is organised the way we like it without the need to compromise. Straight designs create functionality, privacy creates a comfort zone without surprises from intruders and the solidity of the walls will guarantee that it will stay like this for ever. Wouldn't it be great if we could organize our country according to this model? Clear and straightforward guidelines allow for easy evaluation of political decisions - secure national borders guarantee that no intruders enter our comfort zone and all this built solid enough to be passed on to our children.

Fig. 3 Why sculpted environments?

The world does not work like this anymore. The complexity of multicultural societies demands more flexible and more complex thinking patterns. This change in society is being reflected by an increasing number of quite complex architectural projects. The curve, however, is still absent with the exception of Frank Gehry's latest designs. Looking at nature or at sensuously curved sportscars or at celebrated architectural solitaires such as Utzon's Opera House in Sydney, I think there is sufficient proof that highly curved buildings would be welcome. Creating these complex shapes in the computer is still not

easy, finite element analysis allows for their structural evaluation - but how do we build them? - which leads me back to point 4 of the Darren Knight Gallery project.
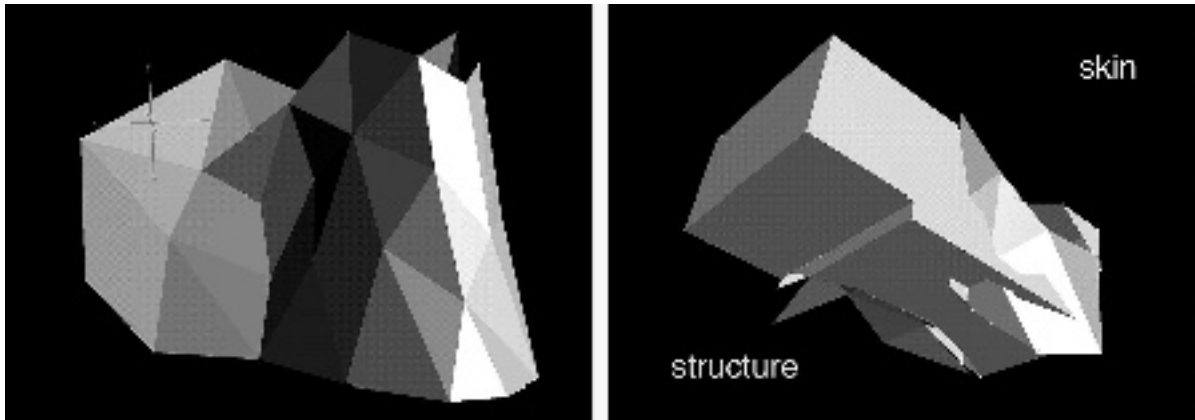

Fig. 4 Creating the design triangle by triangle (left) and one of the 82 different segments (right).

The sculptural design for the gallery was created triangle by triangle in the computer. This ineffective way of designing with a 3D modeller leads to the desired irregularity which would be very hard to achieve with any other method. With the design of the triangulated surface, or skin, completed, a support structure was designed which reinforced the skin but also allowed me to prefabricate segments of the skin as transportable units. Thus the entire design was broken down into 82 totally different segments that fitted through the front door of the gallery. Arranging them in sequence of assembly made it possible to check for "lost" triangles or access to "seams" where the triangles of different segments needed to be joined. Organised in this way pre-production of the segments was estimated to take 2 weeks and a further 6 days were planned for the installation process. Due to storage problems at the factory I had to build everything in the gallery which took 12 long working days with occasional help from some friends.

The successful realization of the design into the full-scale model depends largely on an "unfold" or "flattening" tool that takes the 3D design and produces a pattern for computer controlled cardboard cutting and creasing on a flatbed plotter. Based on a self-written piece of software, a program was written that unfolded all the triangles in a way which minimised the total cutting length and maximized the creasing length. Overlapping areas in the pattern were removed manually at this stage. Thanks to the sponsorship from *Visy Board*, a major cardboard packaging manufacturer, I was allowed to use their speed-plotter and during 4 night-shifts I cut the approximately 2,500 differently shaped polygons from 251 dxf-files. A recently installed 3x5 m. plotter would reduce the numbers of dxf-files by factor 4!
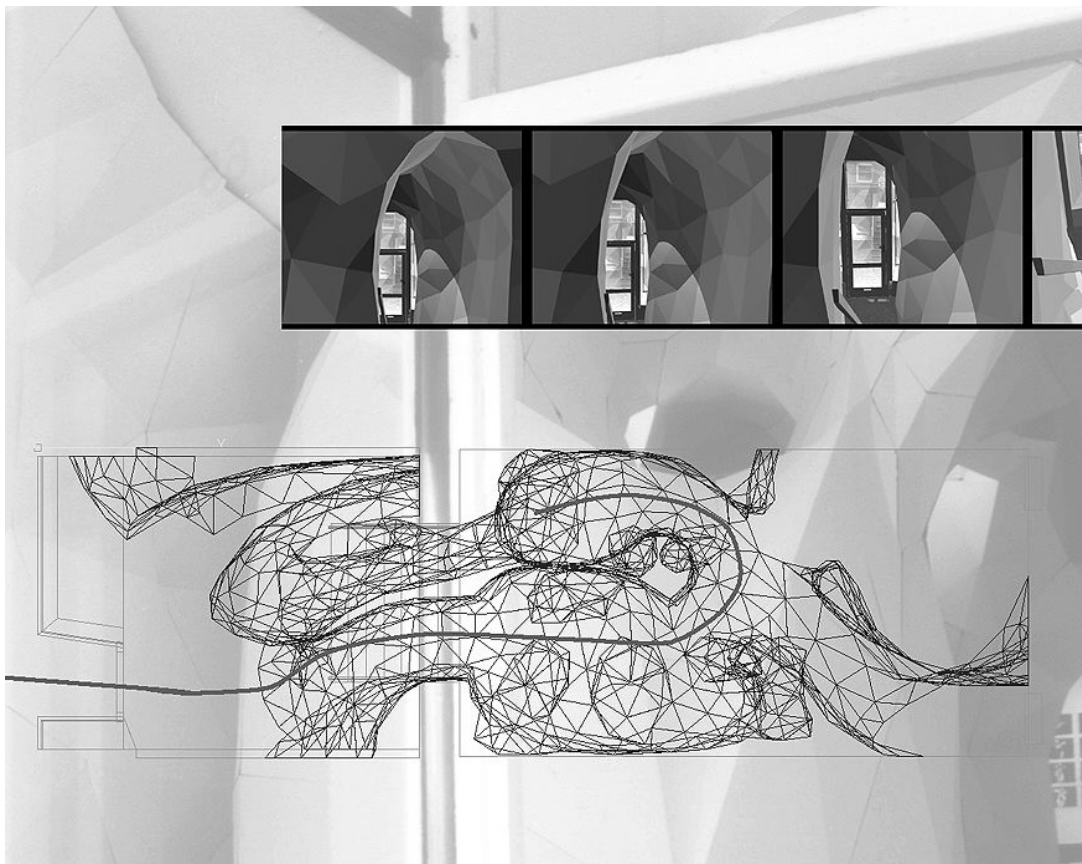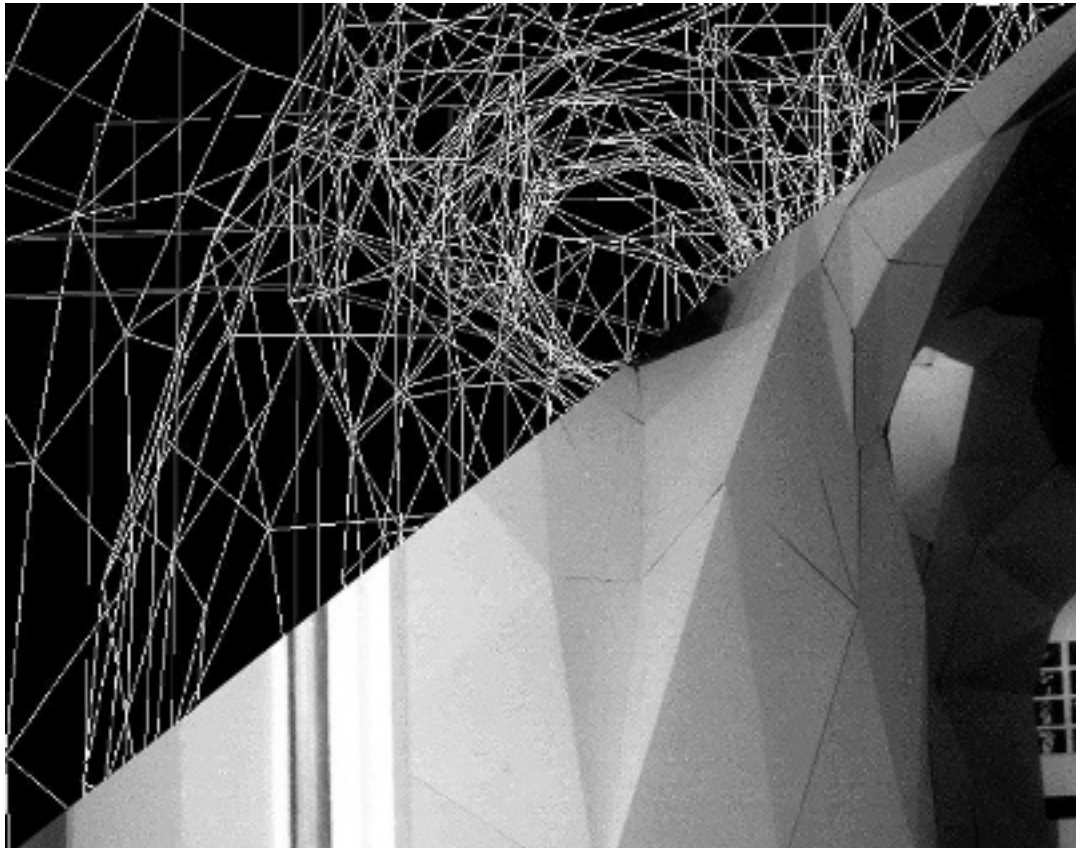
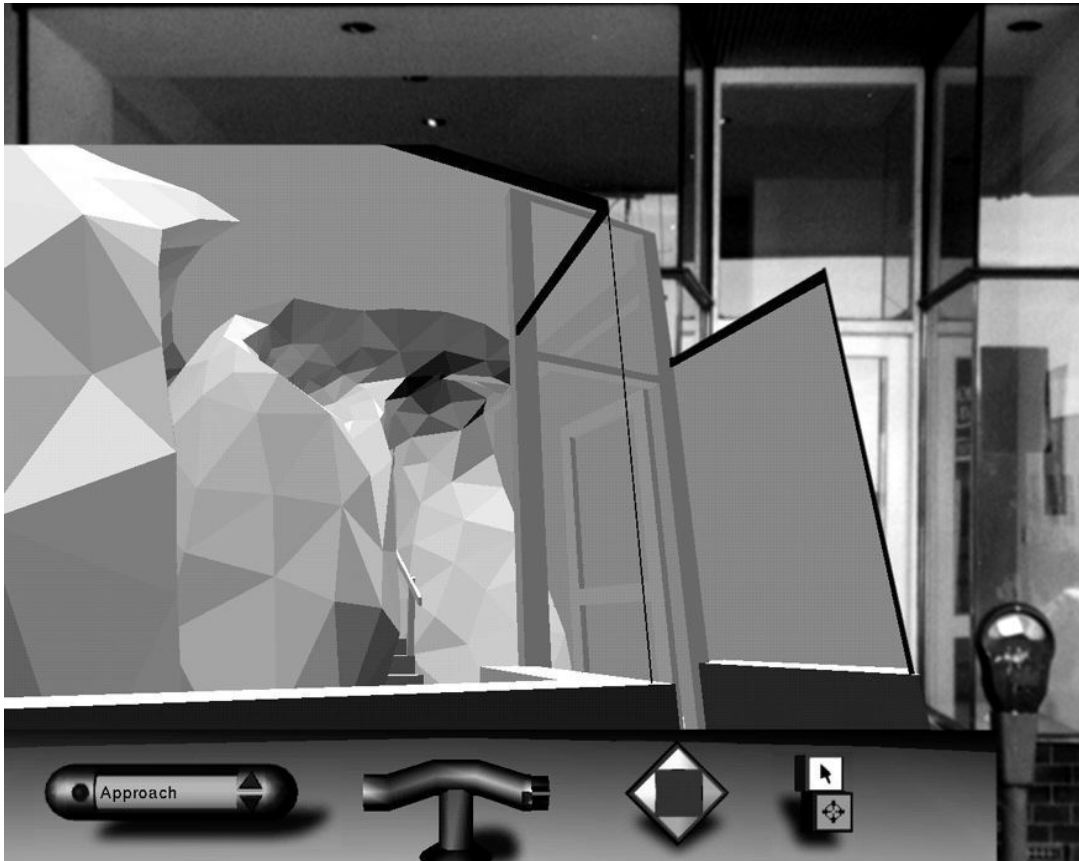Fig. 5a-b Wireframe versus "reality" and video with path through installation.

Fig. 6a-b "Flat" VRML image versus „reality" and a full-scale model.

Virtual Representations Versus an Approximated Full-scale Model

With the Darren Knight Gallery project being a test-case with a full-scale realization as its final stage, I tried to examine the design "virtually" in as many ways as possible through traditional CAD representations to rendered images, rendered fly-throughs, stereo viewing with *Chrystal Eye Technology* and VRML files.

Representation within the CAD program: wireframe representation is incapable of showing the 3-dimensional depth of highly curved surfaces. Rendered views, including hidden line removal take too long in the case of a slightly more complicated design.

Video: Walk-through videos are very helpful - however the linear quality of video restricts the camera angle to a pre-defined path. No real interaction is possible. Production is very CPU expensive.

VRML: The files are easy to produce and it is a powerful way to view a design from many angles. However there are very limited lighting or surface texture options. The system allows you to view only - i.e. it is not possible to correct the geometry directly in the VRML file.

Full-scale model: The impact of a full-scale model is instant. The design is instantly comprehended in its entirety and questionable areas can be evaluated over a greater time span than what would normally be possible in a VR system. Another major advantage is the fact that it is more easy to simulate social activity within a full-scale model. It is possible to invite a number of friends, have a party and discuss right there and then what is good and what is bad.

Cost and Necessary Equipment

Apart from the "unfold" or "flattening" tool the necessary software at the design stage are off-the-shelf products. Cardboard cutting requires slightly modified file formats with different line attributes for cutting and folding. As most cardboard companies use the cutters only for internal prototyping rather than as a service, they do not have fixed pricing structures, however, it is generally much cheaper than laser- or water-jet cutting in harder materials. The cost of cardboard itself is very low compared with other sheet materials. Set-up time depends on how efficiently the data has been prepared before cutting. Some consideration should be given to a support or reinforcement system. With the low weight and high rigidity of corrugated cardboard, however, the requirements for support are quite minimal in most cases.

Comparison with Bricks, Blocks and Panels

One of the most ironic errors the software industry has made in developing CAD programs has been the copying of the simplified drawing board and projective geometry techniques for the design of CAD software interfaces which meant that the simplified geometric language which dominated the pre-computer construction paradigm was literally copied into the computer age. It is interesting to observe how 3D animation packages and visualization software include more and more physics based modeling tools for more natural looking effects (clouds, fire, etc through particle systems - bulging muscles or bouncing hair through finite element etc.). This shift from rigid geometric to dynamic physical modeling will change the modeling part of architectural CAD programs. And a new generation of architects will want to make use of these tools resulting in highly curved, organic geometry options. Bricks, blocks and panels belong to the old generation of rectilinearity, struggling to model anything curved in one direction - incapable of modeling curved surfaces in two directions. The approach shown here might be a first step on the road that will develop architecture from the age of Lego™ to the age of automated fabrication without getting lost in the hype of cyberspace.

The Future

It is certain that immersive VR will play an important role in architectural modeling. It is also certain that it will take at least another 10 to 15 years before the technology is developed to a level where it can suggest reality in a convincing way at a price affordable by the average architecture firm. During the development of immersive VR a calibration process needs to take place that allows to check the suggested virtual model against the reality. The ideal location for the task would obviously be a full-scale modeling lab fitted with an immersive VR system. One thing, though, that I can't figure out - how will they ever manage to simulate the perceptions of going up or down a flight of stairs?

The True Model Concept in Computer Generated Simulations Used in Architectural Design

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Abstract

Most of the studies on the effective use of the potential of computer aid in architectural design assert that the way architects design without the computer is not "related" to the way they design with the computer. In other words, they complain that the architectural design software does not work as the architects think and that the way designers model with computers is not similar to the way they actually construct the model in their brains. Within the above framework, this study initially discusses architectural design as a modeling process and defines computer generated simulations (walkthrough, flythrough, virtual reality) as models. Based on this discussion, the "similarity" of architectural design and computer aided design is displayed. And then, it is asserted that in order to improve the computer aid to architectural design, it is not the issue of similarity, but of the "trueness" of the computer generated model that needs to be discussed. Consequently, it is relevant to ask to what extent should the simulation simulate the design model. The study proposes measures as to how true a simulation model should be in order to represent the design model inherent in the designer's mind, best.

The Concept of Modeling

Human beings understand, create and communicate the world through models in their brains carrying knowledge [1]. Consequently, design and design communication depend on design models, initially created in the designer's mind. The design model constitutes the essence of any architectural product, i.e., from each and every drawing to ‚the building' itself, they are all representations of the design model. Cox describes a model as a mental representation that allows planning for the future [2].

A model is made up by the interconnection of associations and representations which have two time coordinates. The first time coordinate of a model is the actual time coordinate, indicating the time of model formation and will belong to when actually built. The other coordinate is the virtual time coordinate, indicating the potential of the model to be reorganized and revised with respect to feed-backs of the test results after being tested, thus allowing for future planning. The name of the latter coordinate reflects the fact that this coordinate is not actually but virtually, i.e. it is potentially present in

every model (see figure 1). This potential is used when the designer reorganizes or changes the design model with respect to the feed-backs gained through the analysis.

DESIGN MODEL

virtual state of the design model used for comparison with the existing samples

virtual state of the design model used for performance analysis and evaluation

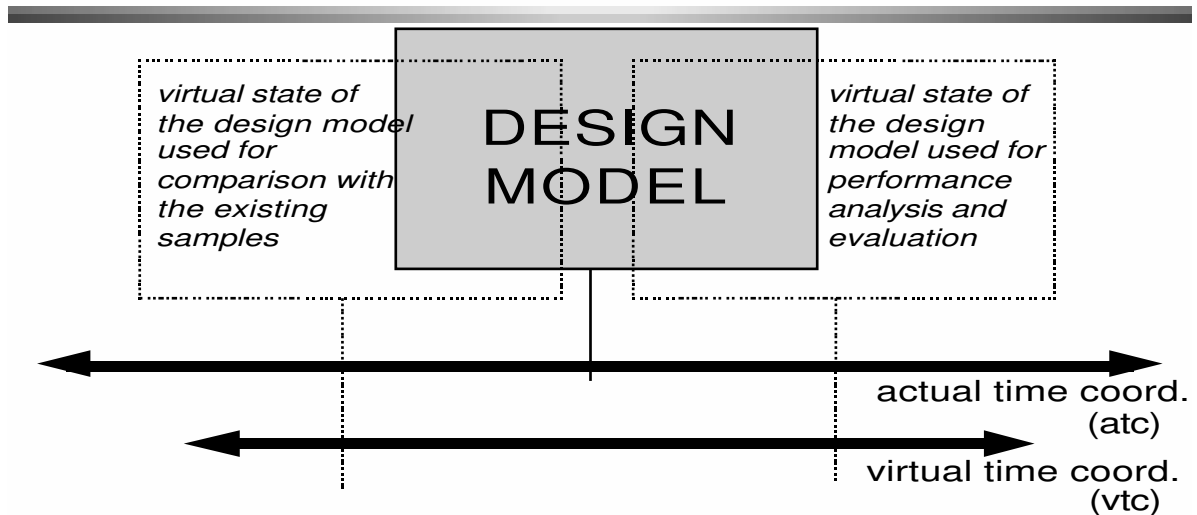actual time coord. (atc)

virtual time coord. (vtc)

Fig. 1 Actual and virtual time coordinates of the design model.

In the age of virtual reality, the range of analysis on the virtual time coordinate spans from evaluation of different design alternatives or performance analysis of the design alternatives (e.g. thermal, structural, lighting and acoustics analysis). Mahdavi explains the operation of these analysis as "...appropriate modeling, which denotes in this context the substitution of the ‚real' experiments/ operations with carefully prepared and computationally executed ‚virtual' experiments/ operations" [3].

Parallel to the definition of the model, which is capable of being changed and reassociated, the model in the designer's mind is fed back as he thinks, talks, and consults about the design.

Baudrillard [4] suggests that modern simulations act as their own referents. This was already the case with the architectural simulations; plans, sections and elevations were already their own referents. Baudrillard's notion of the simulation of simulation, replication of the replica, untrue portrayed as true is in fact the essence of architectural representation. Naturally, this does not mean that architects are liars and that they copy, but indicates that the design process depends on the representation of the mental model. Creation and communication thus depend upon models. Here, creation is taken as design and communication as representation in architecture.

Digital Versus Traditional Media

Architecture, being a profession with a dominant historical background, is known to make use of paper-based methods for design and its communication. These methods are based on paper and pen as indicated by their name and drawings of any kind can be said to be paper-based techniques. Sketches, detail drawings, plans, elevations, sections, perspectives, diagrams, axonometric drawings depicting the architectural design are all paper-based since they are drawn on a paper. Moreover, description of architectural designs through texts and other written or verbal material are included in the paper-based techniques. Both paper-based techniques and models made out of sticks and stones, either partially or completely depicting information about the architectural design can be classified as traditional or conventional media due to their long span of use.

Traditional media lacks modeling capacity which is inherent in the design model formed in the designer's mind. Both paper-based drawings and mock-up models display parts of the architectural design, performance analysis of which cannot be executed upon and design changes cannot be implemented at once. However, one technique, the verbal description, stands within the boundaries of traditional techniques, but break the above definitions to a certain extent. Verbal definitions of architectural design allow changes to be implemented rapidly, being a direct extension of the model in the designer's brain, though lacking visual data.

Traditional media of representation (drawing, texts, constructed models i.e., sticks and stones) do not allow the design model to be totally represented, there always occurs a difference, a gap between design and representation. With the emergence of digital media however, the whole design process (from initial diagrammatic sketches to final drawings, simulations, and representations) proved to be carried out digitally, and the model became the design method itself.

The 4th Dimension in/of Architecture and Dynamic Simulations

Architecture is essentially four dimensional issue, although the fourth dimension never shows up in the traditional media of representation. The fourth dimension in architecture covers the following criteria:

i. Life cycle after architectural edifice is completed, including deterioration, maintenance, changes applied (painting of materials), and restoration;

ii. Dynamic perception of the space by people visiting or living in the architectural edifice [5].

Although being a very important part of the criteria determining the success and effects of architectural design, the 4th dimension of architecture has always been neglected due to the available techniques of representation. It is useful for an architect to be able to simulate architecture in motion since as Greenberg points out, the principal concerns of architectural design are the interior space and the external space of the building and/with its setting. We react to none of these spaces from a static position like viewing a painting, but perceive them dynamically. Consequently, Greenberg suggests that: "To obtain a deeper understanding of architectural space it is necessary to move through the space, experiencing new views and discovering the sequence of complex spatial relations" [6].

Mark [7] defines architecture in motion as the changes of visual image of a building when observed in real time. These changes may be due to the changing of the observation point, related to the dynamic perception of the space (x, y, z, t) and variation of light, variation of use, relocation or transformation of building parts, taking place within the life cycle of the building.

Dynamic Simulations as Models

A computer generated model can be defined as an entity that represents the thoughts, the transformation of the thoughts, their implementation and results altogether. Therefore, a ‚model' can be ‚simulated' and this can result in a "feed-back" process.

A computer model then, turns out to be ‚dynamic' which is subject to continuous change since it is easier than throwing away paper drawings or hand-made models as a result of the ‚feed-back' process. As Beheshti and Monroy describe: "Models are simulations of the real world. They can be static models, simulating the real world at a given point in time. An architectural plan is an example of this. Models can also be dynamic, simulating the real world seen over a period of time and allowing a study of the consequences of actions. In other words, the dynamic models give us the capability to describe changes, and unlike static models, are not rigid and can offer a great deal of flexibility. Therefore, they offer a possibility to oversee the consequences of different directions or courses of actions" [8].

Although the fourth dimension of architecture has a crucial role for the success and efficiency of an architectural edifice, it is seldom referred to during architectural design by conventional paper-based methods. In addition, paper-based methods neither allow easy and explicit analysis of the design nor feed-back from these analyses since they operate on fixed actual and virtual time coordinates. So, they can only display static models, unlike mental design

models. On the other hand, computer generated simulations offer the chance to display and observe the design in four dimensions, operating on a range of virtual time coordinates (see figure 2), thus allowing dynamic models of design similar or "familiar" to the mental design models. The issue that remains here is to make the formation of the computer model familiar to the formation of the mental model, which largely depends on the trueness of the constructed model.
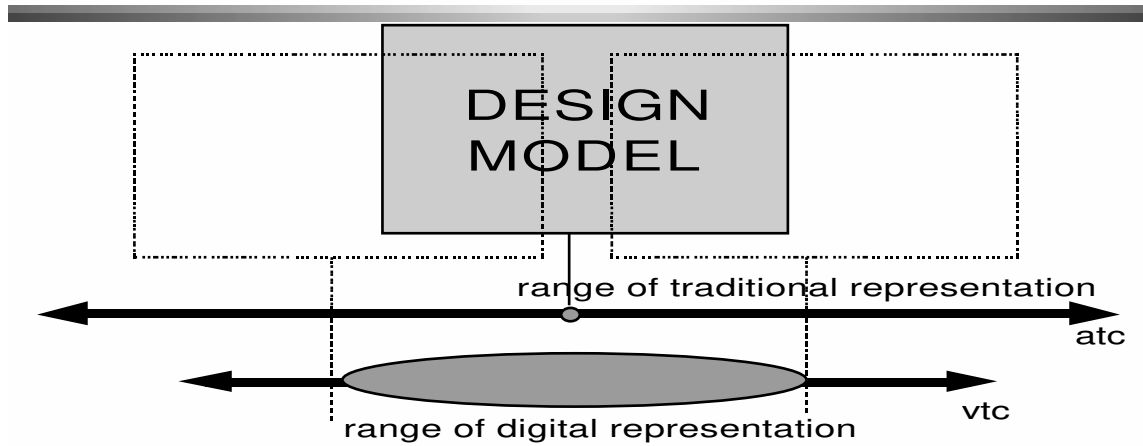

Fig. 2 Ranges of representation of traditional and digital media.

The True Model Concept in Dynamic Simulations

Based on the fact that dynamic simulations operate upon digital models, it is important to note that, however detailed a model or well-made a dynamic simulation can be, it, as of yet, can never replicate, duplicate, or simulate the real visual experience.

There are technical restrictions which prevent any dynamic simulation from giving a perspective as real as direct visual experience. Human eye has a wide perspective which cannot be obtained in a computer screen where walkthrough and flythroughs are displayed. In order to compensate for this, wide-angle lenses are employed which in return distort the view and thus give untrue information about the space. In addition, all walkthrough, flythrough, and virtual reality simulations lack the capacity of the human eye which is to see edges of the frame where the eye is directed to [9]. In the dynamic simulations it is not yet possible to feel the space as if one is inside from the perception point of view. On the other hand, whatever 3D effect is observed, it is observed from a medium which is 2D by definition [9]. Therefore, in order to give a real-looking view, dynamic simulations simulate not what is real, but what is unreal. (In other words, dynamic simulations tell lies in order to depict the truth).

At this point, it is relevant to ask to what extent it is important that the dynamic simulation simulates the reality. The aim of a dynamic simulation should be to show frames similar to the space provided the architectural design was to be constructed, rather than trying to simulate the real visual experience expected to be observed within that space. An approach as in the latter case is to result in a more unreal looking simulation due to the technical restrictions mentioned above. To put it more clearly, it is unlikely to produce a true simulation of a 3D space in 2D media. Moreover, visual experience changes depending upon the characteristics of each person within the space being subjective.

Therefore, the issue of how true a model should be in a dynamic simulation must be related to the aim as Mark puts it "... to a ‚catch a likeness' that might serve to put into focus a key aspect of a design proposal, rather than trying to simulate everything a person would experience when visiting a building" [7]. Consequently, it is a better approach not to expect the results of direct perception within a space, but results of the medium. Technical advances, in this sense, should deal with the provision of visual abstractions more suitable to the architects' cognition, rather than striving to provide almost the same perceptual experience of being inside the architectural space [10].

This gap is most critical at the educational level of the profession as Hoffman sees it: "Representation within an educational environment is at the service of the idea, not necessarily the thing. The students' efforts are directed toward the creation, development and presentation of the graphic tokens. These abstractions remain untested since rarely do the students construct the thing. The distance between the representation of the thing and the thing is inherent in this process. Learning to design within an academic world is, in a large measure, learning to bridge this distance" [11]. It is not only the distance between the thing and its representation but, the distance between the model and the thing since the thing is a representation as well and a much longer one between the model and the representation as well, both awaiting to be covered and it is important to figure out how these distances are to be bridged.

Conclusion

"But now, increasingly, software beats hardware" [12]

In order to supply a bridge between the model and the representation, it is useful to notice that the formation of computer generated simulation software are designed to be tools rather than the assistance method itself. It is true that, the aim of the dynamic simulations is to give an idea about the designed space, but relevant to the formation of the audience and relevant to the purpose of

making such a simulation. However, one of the problems with the currently employed dynamic simulations is their being oriented the same towards different kinds of application needs, i.e. they introduce the same services for different purposes of making a simulation, for different kinds of audience.

However, designers, using digital aid, no longer build models of what they design; rather they build the whole procedure through which they reach the final design. Building of the modeling procedure digitally is not only necessary to reach the final design, but to represent the various stages of design as well. Thus, the digital aid in design will improve in direct relation to the degree of flexibility a designer has in the digital medium. The degree of freedom of the designer in determining the digital method and procedure of design when using a simulation software, determines the actual degree of digital aid [5].

In order to obtain this flexibility, it might be suggested to use the three scales of architectural representation (see figure 3) in relation to the (i) purpose of the simulation, (ii) experience level of the user and (iii) target audience.
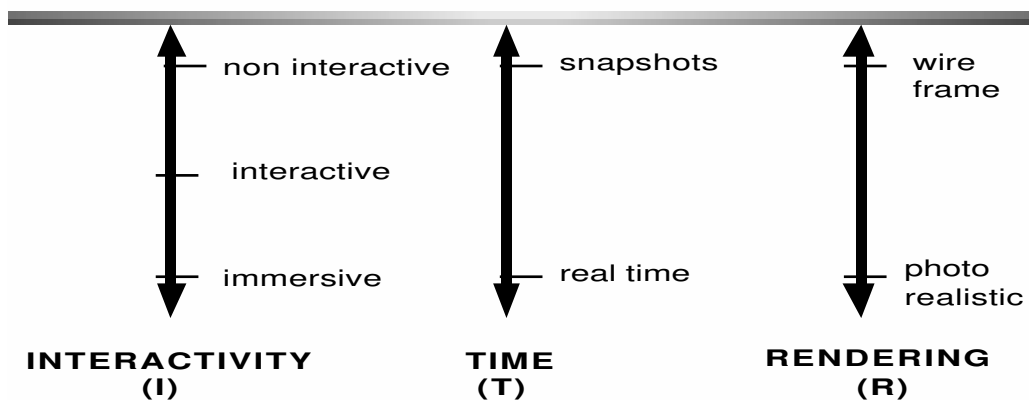

Fig. 3 The three scales of architectural representation.

An initial menu based on this relation matrix used with the simulation software is expected to supply the designers with the chance to customize the computer generated simulations according to their aims and capabilities [5].

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1. Founded: 1986

2. What is a Full-Scale Laboratory or Workshop:
   It's a place for experimentation, research, communication,
   user participation and teaching by means of 1:1 modeling.

3. Field of activity:
   Built environment and mainly housing, collective facilities,
   working places.

4. Aims of the association:
   - to promote 1:1 modeling activities
   - to promote communication of experiences among the
     membership and among them and others
   - to promote collaboration between the membership in common
     projects

5. Official language: English

6. Management:
   EFA-Secretariat: Each member (in turn) for a period of two
   years (the year before and following a Conference).

7. Requisites for membership:
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