Architecture with Machines, Principles and Examples of CAAD-Education at the Technische Universität München

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Design tools

A historical survey

"Design tools affect the results of the design process" - this is the starting point of our considerations about the efficient use of CAAD within architecture. To give you a short overview about what we want to say with this thesis lets have a short - an surely uncomplete - trip through the fourth dimension back into the early time of civil engineering.

As CAD in our faculty is integrated in the "Lehrstuhl für Hochbaustatik und Tragwerksplanung" (if we try to say it in English it would approximately be "institute of structural design"), we chose an example we are very familiar with because of its mathematical background - the cone sections: Circle, ellipse, parabola and hyperbola.

If we start our trip two thousand years ago we only find the circle - or in very few cases the ellipse - in their use for the ground plan of greek or roman theaters - if you think of Greek amphitheatres or the Collosseum in Rome -or for the design of the cross section of a building - for example the Pantheon, roman aquaeducts or bridges.

With the rediscovery of the perspective during the Renaissance the handling of the ellipse was brought to perfection. May be the most famous example is the Capitol in Rome designed by Michelangelo Buonarotti with its elliptical ground plan that looks like a circle if the visitor comes up the famous stair-way.

During the following centuries - caused by the further development of the natural sciences and the use of new construction materials, i.e. cast-iron, steel or concrete - new design ideas could be realized. With the growing influence of mathematics on the design of buildings we got the division into two professions: Civil engineering and architecture. To the regret of the architects the most innovative constructions were designed by civil engineers, e.g. the early iron bridges in Britain or the famous bridges of Robert Maillard. Nowadays we are in the situation that we try to reintegrate the divided professions. We will return to that point later discussing possible solutions of this problem.

But let us continue our 'historical' survey demonstrating the state of the art we have today. As the logical consequence of the parabolic and hyperbolic arcs the hyperbolic parabolic shells were developed using traditional design techniques like models and orthogonal sections. Now we reach the point where the question comes up whether complex structures can be completely described by using traditional methods. A question that can be answered by "no" if we take the final step to the completely irregular geometry of cable-net-constructions or deconstructivistic designs.

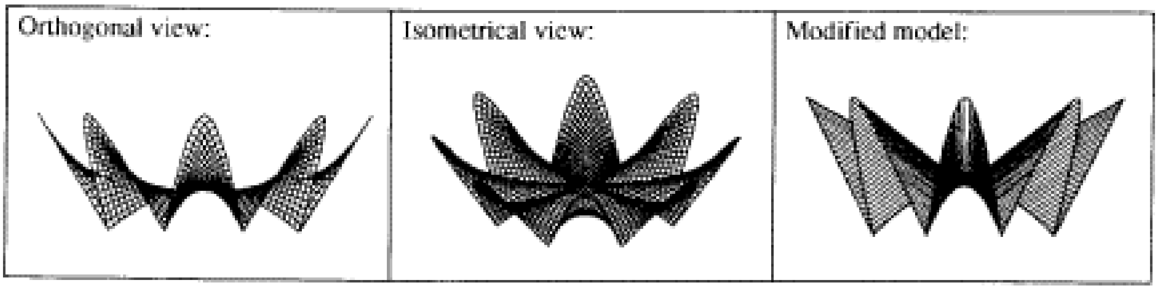
What we see - and what seems to support our thesis of the connection between design tools and the results of the design process - is, that on the one hand new tools enabled the designer to realize new ideas and on the other hand new ideas affected the development of new tools to realize them.

Let's stop our trip through history at this point and return to nowadays situation.

During the last decades the number of persons that are involved into the design process increased steadily with the growing complexity of the buildings themselves. On the one hand we have the planning architect who has to integrate the demands of various specialists - if we think of statics, domestic engineering or acoustics - who produce numerous data, into his design - the call for new planning strategies that deal with the grown complexity becomes louder and louder. On the other hand we have the computer. Indeed machines are not able to sol-c all existing problems, but as "Data Crunching Machines" they offer a suitable solution for one of our main problems - the overflow of information.

If we accept the computer as a tool for communication between different specialists and for integration and - if possible - evaluation of exterior influences like e.g. ecological aspects, economy, construction costs, ... it is only one further step to use it for *realisation* of buildings that became possible by the development of new constructional materials and by giving up traditional, orthogonal building structures. Thinking of spacial structures like hyperbolic parabolic shells, cable net constructions or deconstructivistic models, we can easily accept the idea, that computers could help the architect to put his idea from his brain to a 3D computer model and finally into real world.

If we return to the hyperbolic parabolic shells we mentioned above in the historical survey it is easy to understand how this help could look like. Let's have a look at one of Candela's most famous shells - the restaurant Los Manantiales in Mexico. We assume that no one will disagree if we affirm that a description of its geometry using paper and pencil is a hard way to do. If we use CAD it is rather simple. Here are the results of a student's work that was done during the last few months. Even with rather simple CAD-systems like AutoCAD the generation of the data model is easy to do and - what is much more important - a visualisation from every viewpoint is as simple as a modification of the model.



Let us give you a further and more popular example: You all know the Olympic Buildings in Munich by G. Behnisch and Partners with their significant and unique net construction. During the design process it became evident, that a sufficient description of the buildings geometry using orthogonal sections was rather impossible. We assume you know how the problem was solved - by CAD. The geometry, the length of the single cables and their strain were calculated with the help of computers.

What we see in these examples is, that computer can solve problems that seem to be unsoluble by using traditionally overcome methods. If we summarize all points mentioned above we should consequently accept the machine not only as an electronical drawing board with built-in perspective or calculation that is able to fix a defined step, but as a tool for integration of all involved sciences and especially for the solution of complicated -as well as simple - problems during the design process. So, what we need is a new comprehension of CAAD.

Using CAAD for the design process - a proposition

The typical significance of the architectural design process - alternatives, scale and complexity

The architect who starts a new design has usually rather inexact ideas about possible solutions of a given problem. Step by step he will analyse the complexity of his task trying to integrate - if possible -influences given by the surroundings, by specialists, by law, etc. . In a further step he will develop possible variants, evaluate them and *will* bring the selected one - we hope the best - from a general sketch down to the smallest detail. Now the question is, in which phase of planning the use of CAAD can be efficient and helpful. From the conservative view we might say that CAD's starting point is when all facts are given, the solution is found and no more problems are to be solved - a view that results out of the way CAD is teached and used in our days. In this case the machine degenerates to an electronical drawing board -as we mentioned above. But if we remember the slogan of the "DataCrunching-Machine" and its capability of fast visualisation, qualification, quantification and integration we think this point could be much earlier in the design process - at the very beginning! We will try to demonstrate this:

Top- Down -Development - or: Where is the approximate - button?

If we make the decision to use the computer for architectural design we have to accept the demand that it may not only be used for the repesentation of a fixed model - a given geometry - but for the way we get it. Or in short words: Der Weg ist das Ziel! [1]

Let's begin with a rather simple example you can perform with rather simple CAD-systems like for example AutoCAD:

The question is: What's in a stroke? or better: What's the difference between a stroke that means fassade in the mind of the designer and a stroke that 'represents' a light-weight deviding wall. If there is no difference in geometry the only chance we have is the allocation of a name representing an *idea* - not the final constructive solution. These names function as place-holders which enclose more and more information or sub-elements during the design process. The effect is clear: Every information can be changed or deleted everytime new attributes can be added and all identical structural elements change in the same way. The result is a hierarchical structure of the building, a kind of electronical sketch with some important advantages if we compare it to a conventional pencil-drawing:

1. The grade of detail can be redefined during all phases of the design process. While the *structure as the main constant is* filled with more and more information, the *shapes* are changing.

2. Every manipulation affects all identical elements of the whole building - a generation and visualization of variants is rather simple, possible collisions with earlier decisions can immediately be detected.

3. In every stage of planning an evaluation - in the most simple case a quantification - can be done.

4. And finally we get a well ordered structure of the building which - as experiences we made with students who did their design tasks with the computer and experiences in practice have shown -influences the further development of the design.

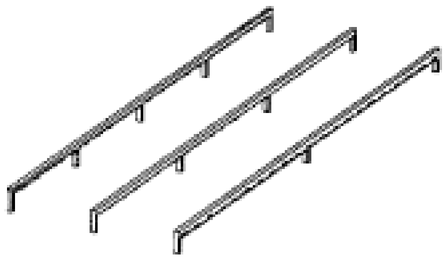
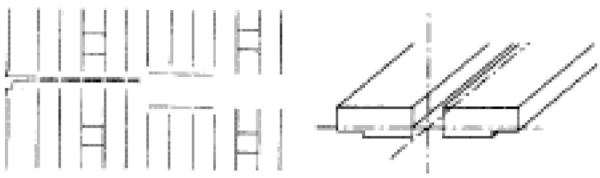
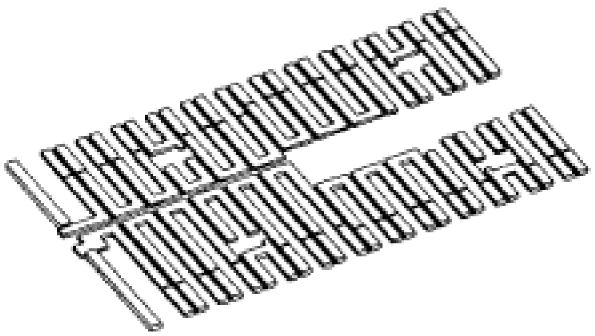
Now we are at the point where the voices against the use of CAD become louder: No conservative designer will accept the medium of his design to affect the *results.* But let's return to the very beginning of our considerations -the historical survey - where we tried to show that in *every* time the design tools affected the design process and its results as they where affected by them. So let's bring the following question to the point of discussion: Is the traditional method to represent a building only in orthogonal sections able to solve all the problems coming up during the design process and is it a technique that will lead to the best solution? Or - if we formulate it a little bit more provocating - are the traditional design methods a tool to deal with todays mostly complicated design tasks, or do they represent a kind of negativ-filter supporting the growing banalisation of our environment. [2]

The parameterized data model

What we have up to now is a data model that is well structured by instantiation; elements are connected to sub-elements and may be to attributes resulting in a top-down hierarchy of the design elements. Now the question is: What happens if one parameter of our building (for example the floor-to-floor height) changes? What happens with the stairs, the deviding walls or the fassade elements? The answer is simple: Nothing! And that's rather unsatisfying.

One possible solution for this problem could be, to tell the computer to understand attributes not only as an affix to the elements but to derive a logical behaviour out of them. In our example a change of the floor-to-floor height would cause the stair to change its length, its number of steps or the rise/run ratio.

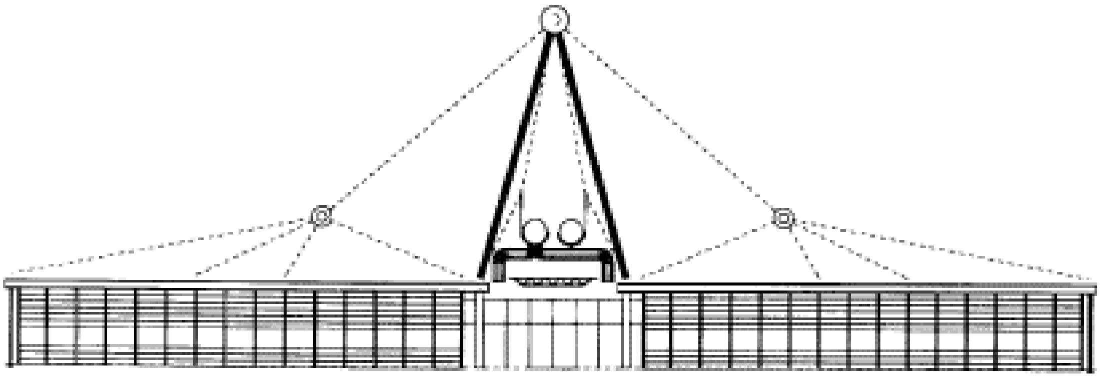
We will give you some examples for that:

	*Parameterized modell of a beam over a row of posts:* The height of the beam is connected to the number of posts and is dimensioned on the base of structural engineering formulas. A simple example for the use of artificial intelligence.
 	*Study of a Third-World-Township:* Axes of a typical part of the township. The connection of the 2-dimensional axes with 3-dimensional (parameterized) information about the building generates a modell of the masses. Parameters for the solution of the ending points and the height of the buildings cause a modification of the whole structure. As the height of the buildings affects the distance between them, the axes themselves are modified. We will give you more detailed information about that later when we will discuss possible techniques of data-organisation.

Now, if we connect the parameters of elements vertically to their subelements and horizontally with each other we finally get something like a self-organizing data model where the change of *one* element causes - if necessary -the change of all others that are affected.

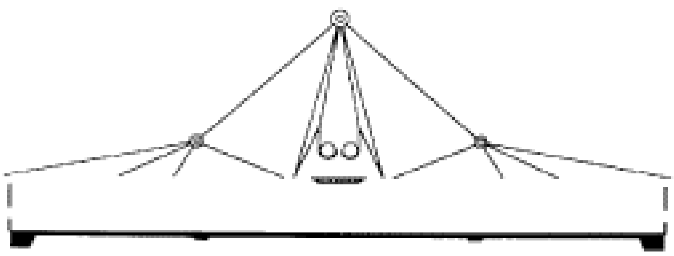
Transposition of our design theory to the teaching of CAAD in our faculty

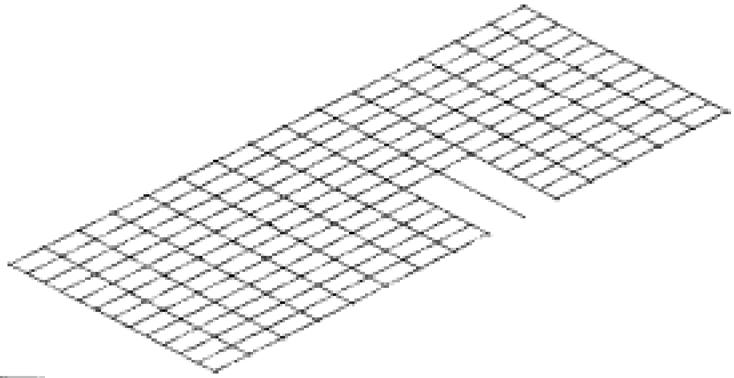
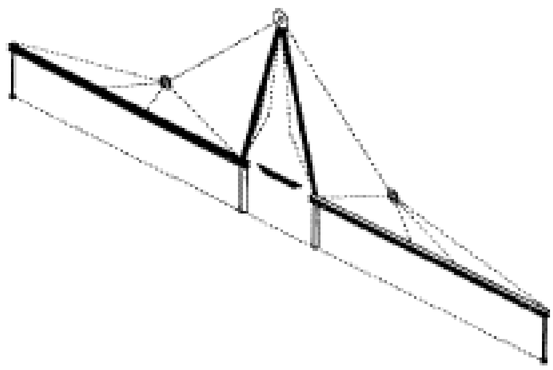
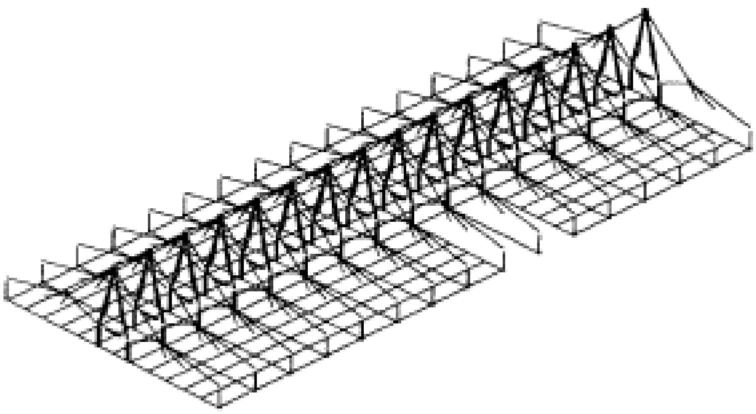
The subtitle of this year's ECAADE is "Experiences with CAAD in education and practice", we finally want to give you a short overview in how we try to give our students an insight to the efficient use of CAD for the architectural design process. We want to do that with a short demonstration of the project we realized during the last half year. We guess, you all know the building: It is the research and administration building of PA Technology, Princeton, New Jersey designed by Richard Rogers Partnership 1984.

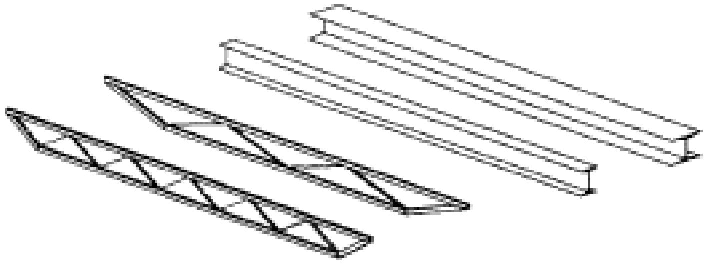
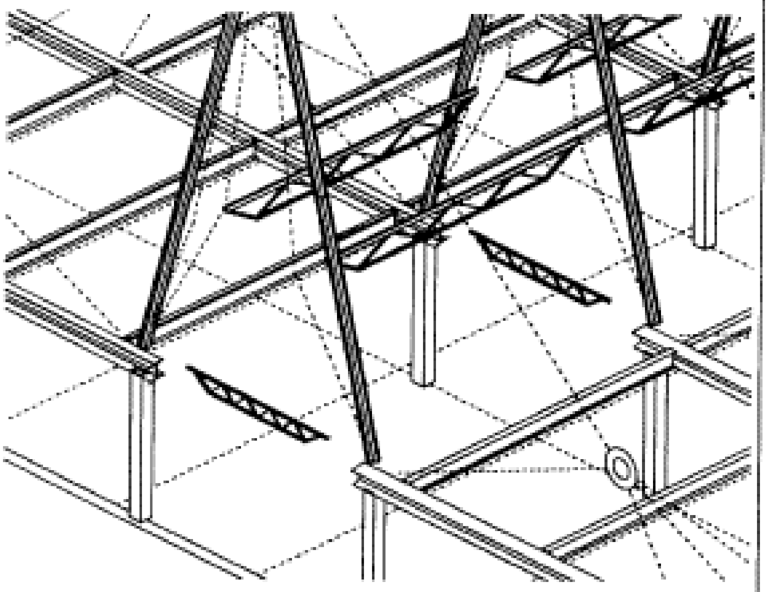


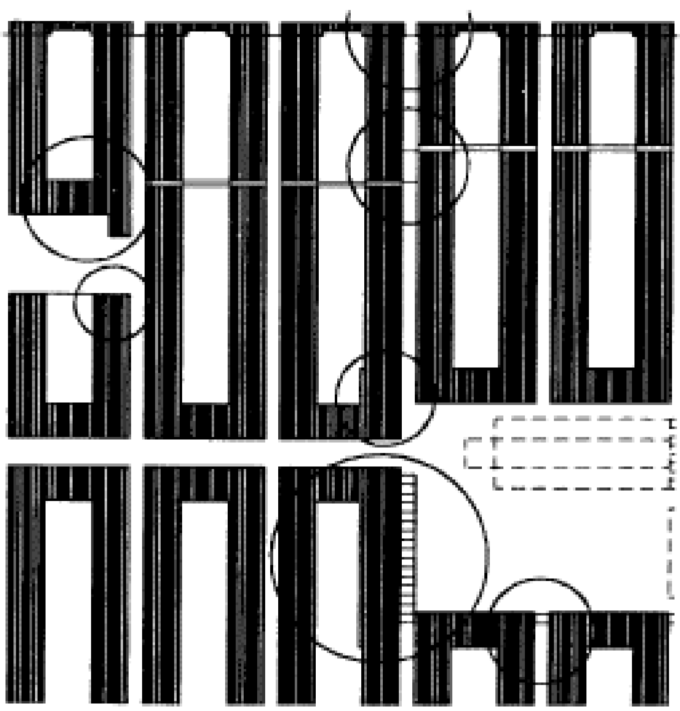
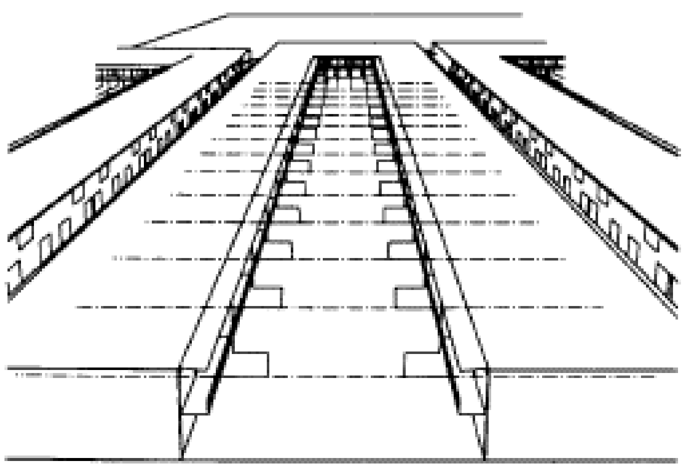
But let's firstly have some considerations about what is CAD and what it can be used for. As you know CAD usually stands for "Computer Aided Design" ~ so we come to the following question: How do we have to deal with CAD to meet the demands of the word "design"? Or in other words: Where is the point where we have to replace the word "design" by "drawing"?

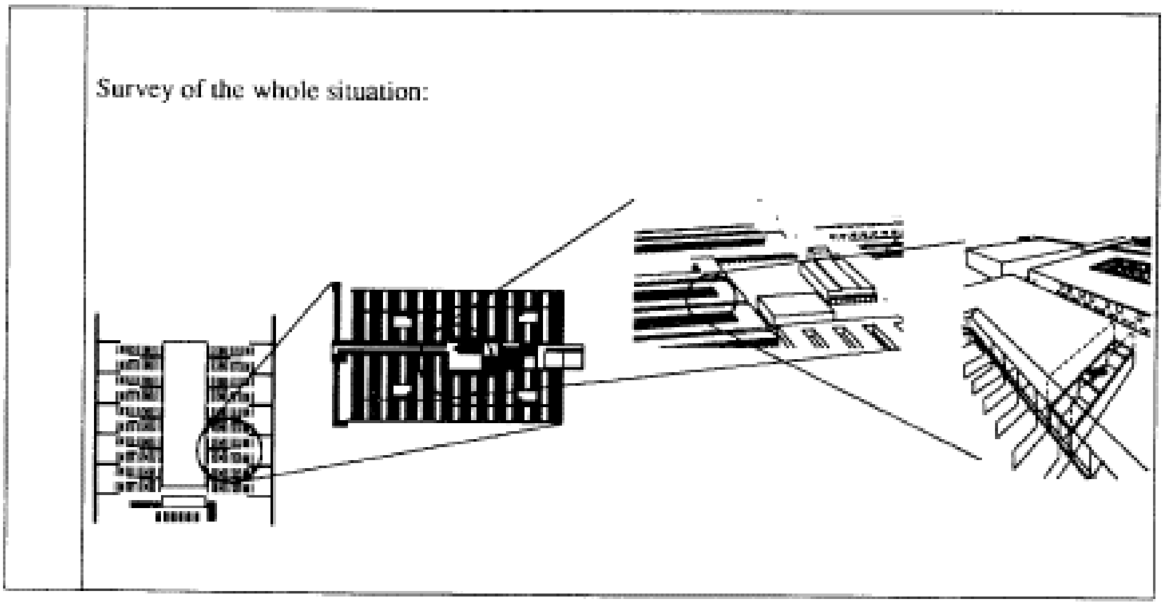
To answer these questions let's have a look at the following four phases detailing the possible use of CAD, the means and the method of organisation:

	Aim	Means	Organisation
1	Graphical editing	using built-in procedures	Layers and unnamed elements; bottom-up construction
			Step 1: Cross section of the building using simple drawing and editing commands containing only two-dimensional information.

2	structural drawing	composing elements to reasonable groups	Blocks of elements; handling of scale- or variant-specific parts; structural top-down-development
			Longitudinal and cross axes of the building that are defined as AutoCAD blocks.
			New definition of the block "cross axis". 3D-information is added to the 2D-stroke.
			Result of the new block-definition; all identical elements change in the same way.

3	Structural drafts	creating components by connecting simple algorithms to groups	knowledge capsules: first approach to self-organisation
			I-Beam and framework as structural elements. The geometry is defined by parameters and can be changed changing these.
			Part of the Rogers-project with I-beams and frameworks inserted. If the geometry of one girder is changed the user can decide whether all others shall change in the same way or not.

4	Production of coherent building models	bounds between the components and general constraints of the design	Project segmentation horizontally through topographical linkage, vertical top-down-development
	 		Study of a Third-World-Township: A simple ground plan of the axes is gradually filled up with more and more detailed information. Parameters define the solution of the ending points, the height of the buildings, the cross - section, lot partition, etc.. Lot partition



In addition to phase I-our we must say that the possible definition by parameters is analogous to the grade of definition by general constraints of the design problem. In our example - the study of a Third-World-Townscape - economical aspects restricted the number of suitable solutions.

If we try to continue the list, we consequently get - as phase five - a process that generates a design *automatically* using parameters given by the surrounding conditions, like for example the urban context, the list of necessary rooms, economical aspects, etc.. In addition we would have to integrate criteria of a [1] good ' design or something what we call the personal style of a designer.

So we come to the question whether a building can be described sufficiently by numerical data or whether parameters of design quality can be integrated into a machine. Before we answer this question apodictical with "no" lets have some fundamental considerations about the architectural design process:

Architectural design is part of a cultural process reflecting something what we call the formal language of a period and integrating new experiences and new developments. Consequently - as part of this dynamic process - it can not be described by definitively fixed numbers or parameters. What could be done at best is a reconstruction of historical structures as it was tried with Palladios villas. But - as a transposition from history to future seems to he rather impossible - no designer - and no computer - can tell us, how the Rotonda would look like, if it would be designed in our days; only a creative thinking machine could per-form this task - up to now we have only one - the *human* designer'

As conclusion we can say, that the computer is *the* tool of our time; and as each tool it *will* influence the design process and its results. The method of design will become more and more abstract, structured and complex *not* because the medium of the design process - the machine - demands it but because the process itself became more abstract, structured and complex, and the machine gives us the right answer to deal with these demands.

[1] Dale Carnegie: "Das goldene Buch"

[2] Prof. Hübner, Stuttgart: "CAD zum Entwerfen und Verwerfen" 1991