CAAD: Education-Research and Practice
ECAADE Conference 1989
School of Architecture, Aarhus, Denmark

TOWARDS A NEW GENERATION OF COMPUTER ASSISTANTS FOR ARCHITECTURAL DESIGN: AN EXISTING SCENARIO

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knowledge-based architectural design

SUMMARY

The context in which designers operate is becaming more and more complex, owing to the large number of codes, new materials, technologies and professional figures; new instruments are needed, therefore, to support and verify design activity. The results obtained in the first years of 'computer era' were barely sufficient. The hardware and software available today is capable of producing a new generation of CAD systems which can aid the designer in the process of conceiving and defining building objects.

At the CAD Laboratory in the Department of Building and Environmental Control Techniques at the 'La Sapienza' University of Rome, research is being carried out with the aim of defining a new kind of Knowledge-based assistant for architectural design.

To this purpose a partnership has been established whit a private firm called CARTESIANA, whose partners are software houses, designing and building associations.

INTRODUCTION

Design activity as it was conceived in the sixties and seventies is already a thing of the past. The ever-growing dimensions of the activity, the innumerable links connecting designers and consultants, consultants and the University, and the latter with State and Regional Research Institutions and firms, along with the huge development in the restoration and reconstruction sectors, with its own special problems; concern for energy-saving in management and construction, and closer attention to static security, fire, prevention of intrusion and comfort have all contributed to ensuring that the building operation is, as it were, guided by invisible strings. In this context each operator is aware of the presence of little-observed factors, but only after having made decisions which prove to be unfounded. This happens not only at the level of individual operators but also at the level of medium and large-scale designing firms; with the difficulties of communicating and capitalising upon experience, it almost seems as if the system of "architectural design" has lost its transparency.

COMPARISON WITH OTHER TYPES OF DESIGN

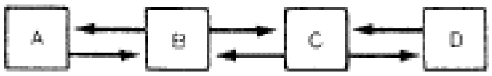
All this had already happened as far as the manufacturing industries were concerned under the pressure of new technologies, processes and materials which overturned long-established situations: there was a crisis in the American model of the closed-system firm, replaced by the Japanese pattern of reciprocal quality control with constant interchanges of knowledge (fig. 1). At the same time, the mechanical industries, and especially data-processing/electronics, because of the turbulence typical of a period of innovation, drew closer to the building industry, which has always been characterised by severe cyclic crises and increasing mobility of the product[1]. Now it could be said that a part of the failure in techniques and relative CADd software applied to architecture in the 70's and early 80's can be attributed to the "primitive" state of the other industries as compared to building - i.e. a contradiction of the viewpoint which prevailed until a little time ago[2]. It follows that the software for the design of a motor vehicle of the nineties is nearer to the design problems of building design than drawing which went under the apparent general title of "general purpose" ever was. In fact we have moved on in this industry from a stage of automation of the process, based on a summation of technological "culture", to a global technological vision in which idea creates both the techniques and the market. Another example which shows the great difference of designing between the eighties and the seventies can be found in the F.1 engines; in the earlier period the engine was conceived of as a "closed" entity, and within the context of certain rules, restricted parameters. eight or twelve cylinders, angles between the bore of 60°-90°-180°. Now an engine is not only thermodynamics, power and dependability, but also aerodynamics, chassis and stability, which correspond to a greater plurality of division, disposition and distribution of the cylinders.

We can confidently reject the assumption of Le Corbusier. no longer houses as "habitable machines", but cars as "travelling homes"; it is time that architects began to think a little about cars ... (fig. 2).

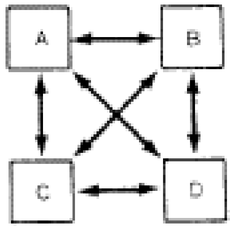
ARCHITECTURAL DESIGN

Now that the phase of architectural design as the handmaid of mechanics is over, we can more justifiably concentrate on the specific detail of building design seen from now onward as a guideline for other types of design. In order to do this it may be useful to give a brief critical glance at what has taken place over the last twenty-five years.

The mid-sixties were characterised by the "systematic" fashion of design, in which criteria of "scientific", and "objective" standards were applied to design decisions[4][5]: in reality these were no more than simple flow-chart established in a stabilized external pro-

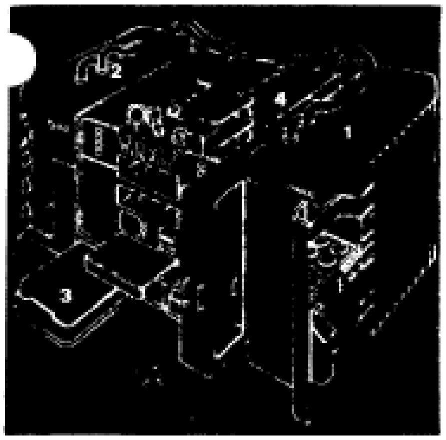


adjacent interchange

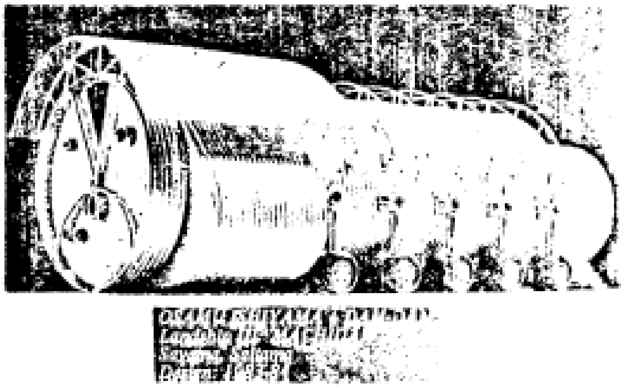


reciprocal interchange

fig. 1



Joe Colombo's design



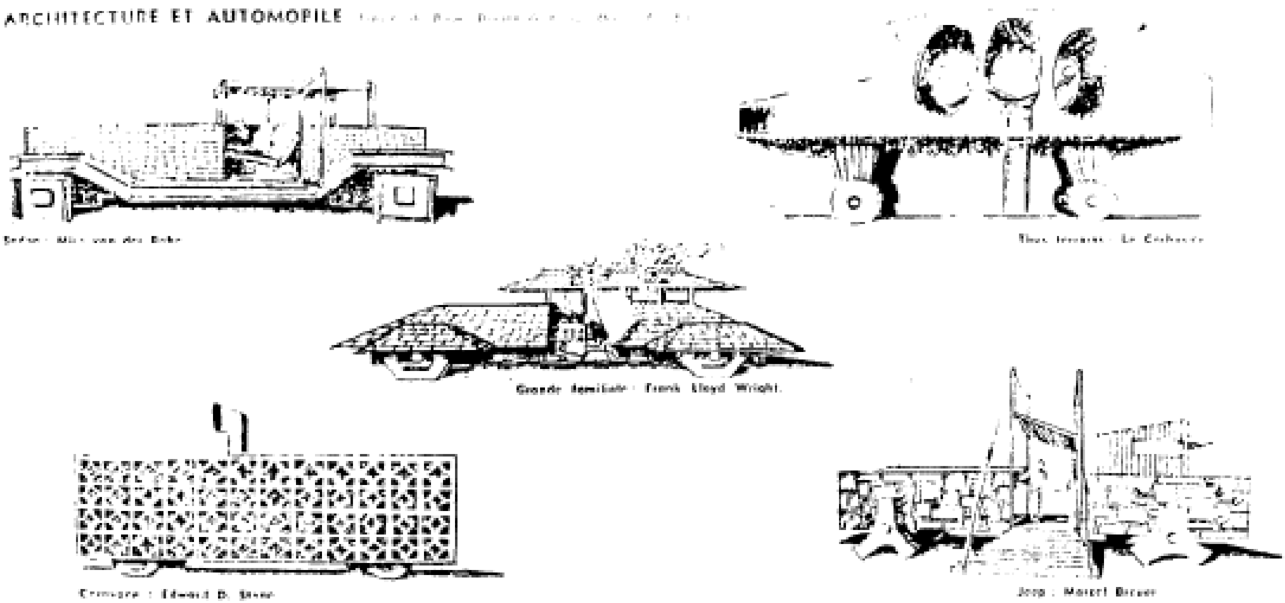


fig. 2

ductive context, and poor in ideas (with the decline of the International Style) in the internal context (the domain of specific knowledge). All this was an extreme ideological consequence of the Modern Movement: its claim to be the only "rationale style". Building was viewed as an activity aimed at series construction, in view of imminent industrialisation, and it followed from this that the comparison and choices must take place at the level of the assemblages. Design was based on graph theory.

But at the end of the sixties, the consequence of this manner of operating were already becaming clear: a "systematic" progressive levelling and impoverishment of the quality of architecture[7].

The early seventies were characterised by two lines of research: on the one hand there was an insistence on the automatisation of architectural design[8]; indeed it was even presumed that architects would became redundant; on the other hand there was a more pragmatic approach, in which programs were designed aimed at specific sectors of design such as the verification of structural dimensions, estimates of quantities, costs, energy consumption and graphics. At the end of the 1970's, the first systems of assisted design as we now understand it appeared, along with solid modellers.

On the basis of this experience, a more mature consideration of the meaning of the concept of design began. This was no longer defined univocally (as a totality of choices within a dominion), but plurally, like light for which a dual definition exists as particular/undulatory. For this purpose, the concepts of representation, search for acceptable solutions, acts of faith [9] and craftsmanship (i.e. modification of models already proved), metalanguage, and so on, are all required. From all this it became clear that what we have here is not inadequacy of the instruments but rather their non-conscious, or better still, distorted use. The sign (=image-message) is confused with the technical drawing (=structured set of decipherable information which can be formalised), and the _quality of lines and points present on the page. This was made clear by the failure of all the neutral forms of interchange, limited to the translation of geometry, by the use of modellers as simple renderings, by the different data-structure for each different application. Above all, the instrument was deficient in one thing - scale.

The concept of scale in architecture was totally different from that of mechanics. The former was a dimensional relationship of the object to its Monge projections (fig. 3), the latter a "contextualiser" of forms (fig. 4) or better still, a certain order which gave meaning to the signs (fig. 5)[16] .

At the moment (possibly for CAD-drafting culture as well), it is foreseen that the positions of architecture and mechanics will draw closer again, and thus also the two concepts of scale: where the design is seen as an assemblage of mechanical parts (e.g. the Nimes Media-gallery of Norman Foster), or there is a loss of the form - dimension couple (e.g. Siemens laboratories of Stirling as drums), and of the relation between form and function (e.g. the "Colonnes" housing units of Ricardo Bofill). All this is because CAD-drafting leads to an

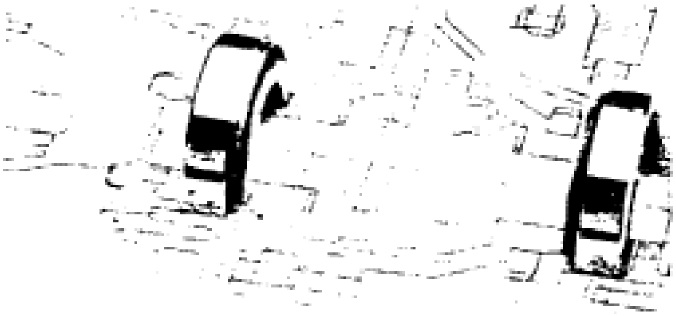
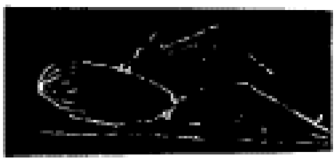
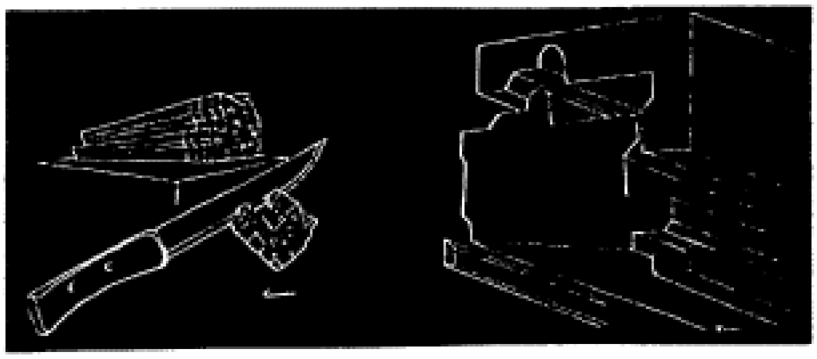


fig. 3

CESAR PELLI, Pacific Design Center, Los Angeles, 1976





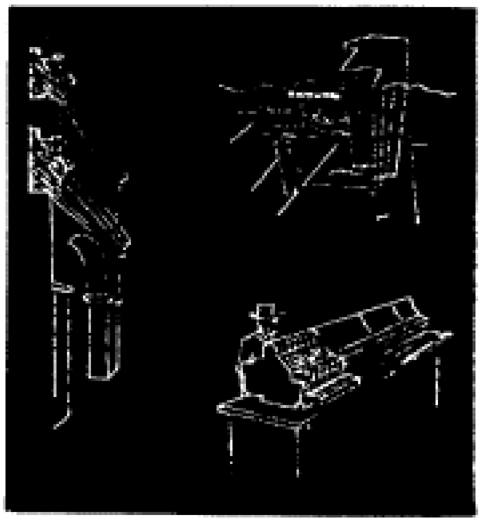
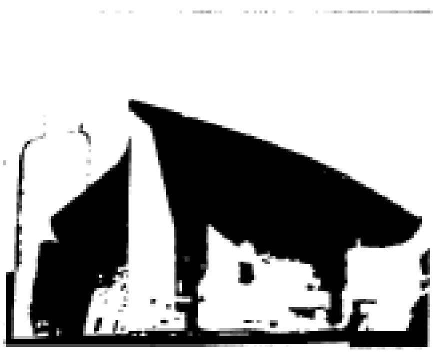
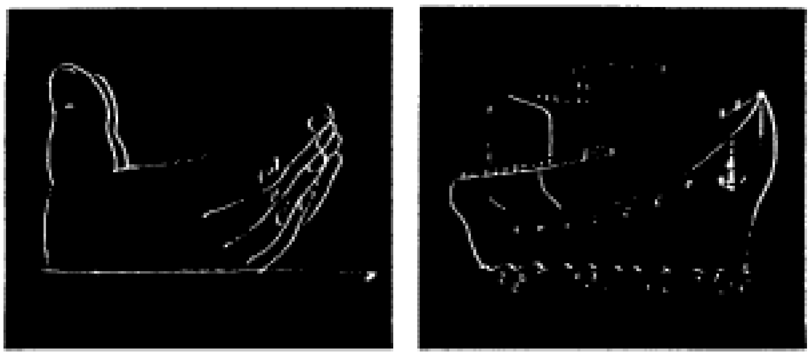
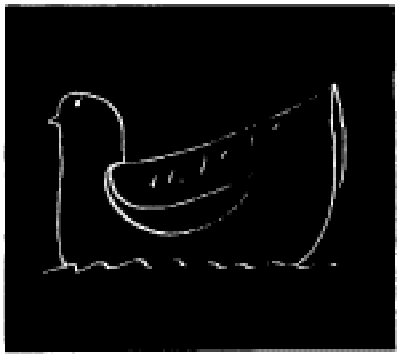


fig. 4



LE CORBUSIER, Ronchamp Chapel, France, 1955





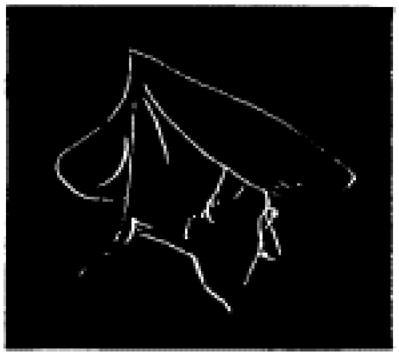


fig. 5

elementary discomposition, a constructivist stratification, a decontextualisation. All this is at the level of exemplary interventions, but for "traditional" and everyday design, a deep abyss lies between instrumentalisation and praxis.

Ten years ago researchers strove to find new methods in the representation and simulation of the building through instruments and techniques proper to Artificial Intelligence, and for this reason, there was no longer talk of "new design modes" which were to be into effect on the available instruments, but on the contrary of bringing the interface and the methods as close as possible to the designer. This is above all because, as design activity cannot be formalised in simple terms and is not yet sufficiently known, it is opportune to work directly on conceptual symbols rather than on images (=coordinators of knowledge, linked to the signs, and of a more indistinct nature[10]), which are to be found at deeper level of knowledge. Others tried to formalize a systems of verification for the codes with regard to fire safety[11], or the use of CAD for the first stages of design[12], or further research into the architectural semantics of the building unit[17], and the configuration of HVAC systems[18]. Another thread of research which has revived somewhat is that of optimising the topological configuration[19], and automating parts of the design of a building such as the kitchens, staircase, etc. But there are still considerable difficulties in introducing automatic techniques, suitable in an assembly-process with invariable elements, into a highly innovative context.

This is also because we have passed from considering building as an activity aimed at the construction of prototypes, to that of designing prototypes; in which the comparison among the building units no longer take place at the level of compatibility and combinability but of "ideation" (e.g. Norman Foster's models for the Hong Kong Shanghai Bank).

For these new needs, in which the designer is free to invent solutions and constraints from time to time, and is placed in a position to choose in the best-informed way possible, other instruments are needed, which will also make use of already developed software packages.

A SUPPORT SYSTEM FOR ARCHITECTURAL DESIGN

In order to create instruments for the support of building and architectural design, it is therefore necessary to adopt a methodological approach and a highly innovative operative context.

The research activities of the Department of Building and Environmental Control Techniques, guided by above considerations, are aimed at the creation of a Knowledge-based Assistant for Architectural Design (KAAD), which will be capable of making it easier to define and specify the design goals, evaluate the performance provided by the decisions made, and compare them with a given set of goals.

KAAD has thus been conceived as an instrument of representation and simulation, which in the hands of the designer can carry out complex tasks aimed at making all choices adopted explicit, rather than defining them.

The general structure of the system is based on the following four modules[12][13][14]:

- User interface and control system, which is responsible for the communication between the user and the system. The control module is also required to perform the task of running the evaluators necessary for determining the correspondence of the design decisions made to pre-established constraints;

- the knowledge base the software component of the system, in which a conceptual model of the building organism is memorised. In the knowledge-base are contained three types of elements which contribute to create a representation of the section of knowledge under review: the prototypes, the instances, and the relational matrix [15]. The prototypes are predefined objects, and represent the basic knowledge of the system. The description of the objects is realised through SLOT-FACETS couples. Each slot represents a particular feature of the prototype, while the FACET designates the totality of values which can be assigned to that characteristic. The instances are specific examples of a class of objects defined by a prototype, from which they inherit all their characteristics. The relational matrix establishes the relations among various classes of prototypes and instances, and provides the system with the information related to all the components linked to a certain determined object. Every type of entity present in the knowledge-base is provided with a totality of operators which are capable of creating it, eliminating it from the knowledge-base, modifying it and placing it in relation to other entities;

- the evaluators are specific programs aimed at the determination of certain characteristic of the building units, and they are normally created by experts in the sector. Each of them is made up of a program aimed at verifying the correspondence of the building unit considered in relation to a determined object such as, for instance, distributive needs, costs, environmental wellbeing, etc.;

- the design goals are represented in the system by a list of values related to the aspects which are held to be necessary for the evaluation of correspondence e.g. costs, functional requirements, social implications, and so on. The system will be capable of allowing the designer to define the goals which he considers necessary to take into account both in a priori terms and in the course of his designing activity.

THE CONSORZIO CARTESIANA (CARTESIANA CONSORTIUM)

What we have outlined above shows the complexity of such a system, and hence the importance of the work-group for its realisation.

The capacity to identify relevant information in a given operative context, and to codify it completely, assumes an importance equal to the type of formalism and the methodological approach adopted. On the other hand, the creation of this kind of system also requires enormous efforts of programming and sophisticated level of computer skill.

These considerations have led the Department of Building and Environmental Control Techniques to acts as promoter for the constitution of a body which will devote itself to the realisation of the KAAD system.

The CARTESIANA consortium (Computer Aided Research Team for Expert Systems Implementation for Architecture and Network Applications) came into existence in this context, and is made up of partners who work in the fields of building and computers. The various elements making up the Consortium are as follows :

- ENIDATA S.p.A, which is one of the largest Italian dataprocessing companies, belonging to the ENI Group. ENIDATA and another company of the group, (TEMA, S.p.A.) which concerned specifically with cartographic technology, contribute to the realisation of the project by providing skill and know-how in the sectors of computer graphic, artificial intelligence and knowledge-engineering;

- CRESME S.p.A. (Centro Ricerche Economiche Sociali e di Mercato per l'Edilizia), which contributes to the project with its knowledge of the building market and the needs of the users through its own software house, CIDS;

- ICIE s.c.r.l. (Istituto Cooperativo per l'Innovazione Edilizia) is part of the League of Cooperatives. It is the mouthpiece for the needs, and also the know-how, of a large number of operators such as design firms and companies;

- ISVEUR S.p.A. (Istituto per lo SViluppo Edilizio e URbanistico), an association which brings together construction firms operating in the building sector. It has acquired substantial experimental knowledge in the building sector, and has specific skills in the activity of management of the building process;

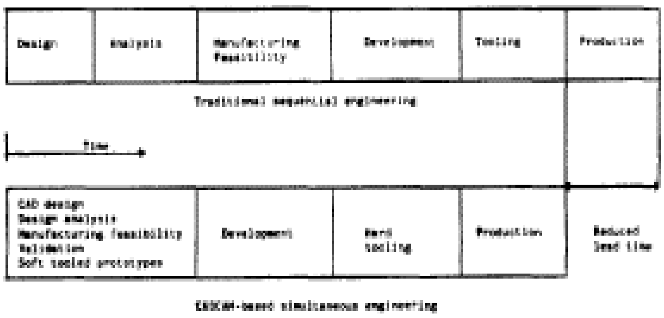
- Dipartimento T.E.C.A. (Building and Environmental Control Techniques) of the Faculty of Engineering of the 'La Sapienza' University of Rome' responsible. for the scientific activities of the Consortium. It is assisted by a technical-scientific committee of which Professors Tom Maver, Yehuda Kalay and Gianfranco Carrara among others are members. It acts as the meeting point for the needs of various elements of the Consortium.

The CARTESIANA Consortium thus brings together in a single structure different elements which represent the demand of the systems for the management of the design process (ICIE, ISVEUR), and those whose task is that of satisfying this demand by creating-this type of instruments (ENIDATA, CIDS).

The research programme which the Consortium is carrying out is divided into three years. At the end of the first year it is anticipated that a first prototype of the system will have been realized, capable of demonstrating the potential of the methodological approach adopted. The 'Maison Citroan' is the first instance implemented.

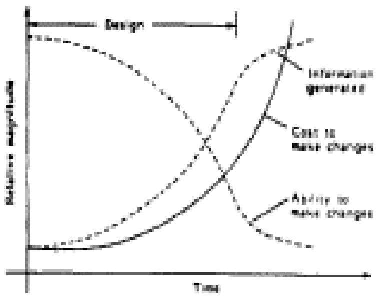
CONCLUSIONS

The present economic situation favours the development of this kind of software. In the present post-industrial society, there are project management companies which need design instruments capable of guaranteeing required times, and reliable and known building procedures (not innovative as a process). In these cases, design as composition is excluded, since we are dealing here with single-object design, in the sense of functional correctness. Another favourable factor is the average size reached by these companies, which justifies the investment and the fact that subcontracting firms, thanks to their substantial specialist skills, operate almost constantly, thus reducing the effect of market fluctuations[1].
The advantages expected are not aimed primarily at a reduction of the costs of design and planning, so much as a saving of overall time (fig.6), and a reduction of the overall costs of the product, which depend to a great extent on the first stage of design (fig. 7).
The great complexity and the fragmentary nature of the building industry are in any case taken fully into account, as well as the unresolved problems of efficient data bases and the semantics of the building object, which lead us to take into account the difficulties of realisation and acceptance likely to be met by Computer Assisted Design, bearing in mind the failures of the 70's.
The hopes of the research now in progress are of a new knowledge of the design process, and a new synthesis of the simulation, and hence the conception, of the building object, backed up by the great richness of the most recent works in architecture.



Comparison of 'sequential' and 'simultaneous' engineering

fig. 6



Impact of design on end-product cost

fig. 7

ACKNOWLEDGMENTS

The research activity which the CARTESIANA Consortium is carrying out is financed by the Italian National Research Council.

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