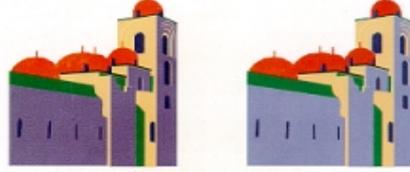


Multimedia and Architectural Disciplines

The 13th European Conference on Education in Computer Aided Architectural Design in Europe



MULTIMEDIA AND KNOWLEDGE-BASED COMPUTER-AIDED ARCHITECTURAL DESIGN

Gianfranco Carrara,
Giuseppe Confessore,
Antonio Fioravanti and
Gabriele Novembri

Department of
Architettura e Urbanistica
per l'Ingegneria
University of Roma "La
Sapienza" - Rome, Italy

Abstract

It appears by now fairly accepted to many researchers in the field of the Computer Aided Architectural Design that the way to realize support tools for these aims is by means of the realization of Knowledge Based Assistants.

This kind of computer programs, based on the knowledge engineering, finds their power and efficaciousness by their knowledge base.

Nowdays this kind of tools is leaving the research world and it appears evident that the common graphic interfaces and the modalities of dialogue between the architect and the computer, are inadequate to support the exchange of information that the use of these tools requires.

The use of the knowledge bases furthermore, presupposes that the conceptual model of the building realized by others, must be made entirely understandable to the architect .

The CAAD Laboratory has carried out a system software prototype based on Knowledge Engineering in the field of hospital buildings.

In order to overcome the limit of software systems based on usual Knowledge Engineering, by improving architect-computer interaction, at CAAD Lab it is refining building model introducing into the knowledge base two complementary each other methodologies: the conceptual clustering and multimedia technics.

This research will make it possible for architects navigate consciously through the domain of the knowledge base already implemented.

Introduction

The concept of Knowledge-based assistant for the architectural design seems by now broadly accepted by the researchers and by the operators of the field and it is unanimous the conviction that the future of the CAAD will have characterized with this type of tools.

Many of the commercial products currently available in their more recent releases begin offering functionalities inspired to this new type of tools. While the first experimental software systems begin to measure with real problems, it appears evident the lacks which could make them unusable to the practical purposes.

These problems could be synthesized with the difficulty in navigating through the knowledge base, which derive essentially from the insufficient understanding that the architect has upon the information contained in the software system. In order to expound entirely problems point out later, it will refer to the researches developed at CAAD Lab of the Department of Architecture and Town Planning of the Faculty of Engineering of the University of Rome "La Sapienza", that have carried out the implementation of a software system based on knowledge engineering: KAAD.

The KAAD system

KAAD (Knowledge-based Assistant for Architectural Design) is a software system including a knowledge base about the hospital buildings with specific reference about those ones for the care of the infectious illness. The structure of the system is shown in figure 1.

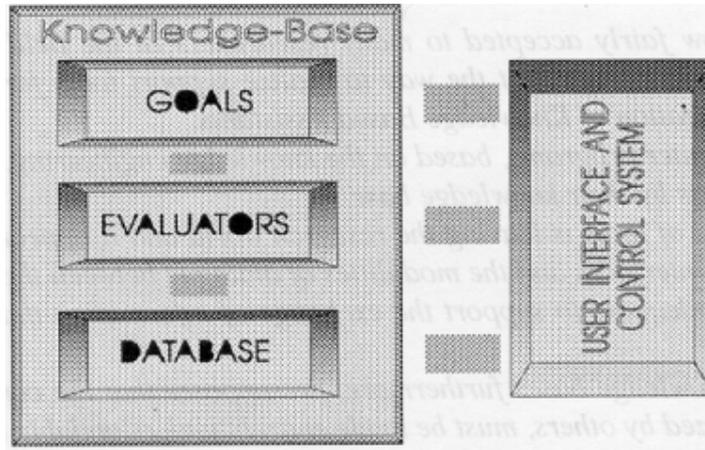


Figure 1 - Structure of KAAD system.

KAAD is able to verify the choices selected by the architect with respects of a given set of constraints which could be imposed by the existing regulations or represent goals that the designer intends to reach.

In the knowledge base it has been represented: the prototype-objects of the building; his components; the instances of these objects; and the constraints that these must satisfy.

The definition of the prototypes and the definition of the constraints derives from a design activity, developed by whoever realized the knowledge base, that could not be, and actually is not, the architect that afterwards will use the system.

The established relationships between the one defines the knowledge base and the architect is for many points of view similar to what characterizes the existing relationships between the designer who defines a preliminary design or building programme, and that one will develops the final design using these intermediate results. The type of relationships is just similar because, in the process of knowledge base definition, the system doesn't introduce constraints which in no way impose design approaches, but only explicits the rule prescriptions. The real objects are represented by means of characteristics and attributes.

The design process can be represented in figure 2.

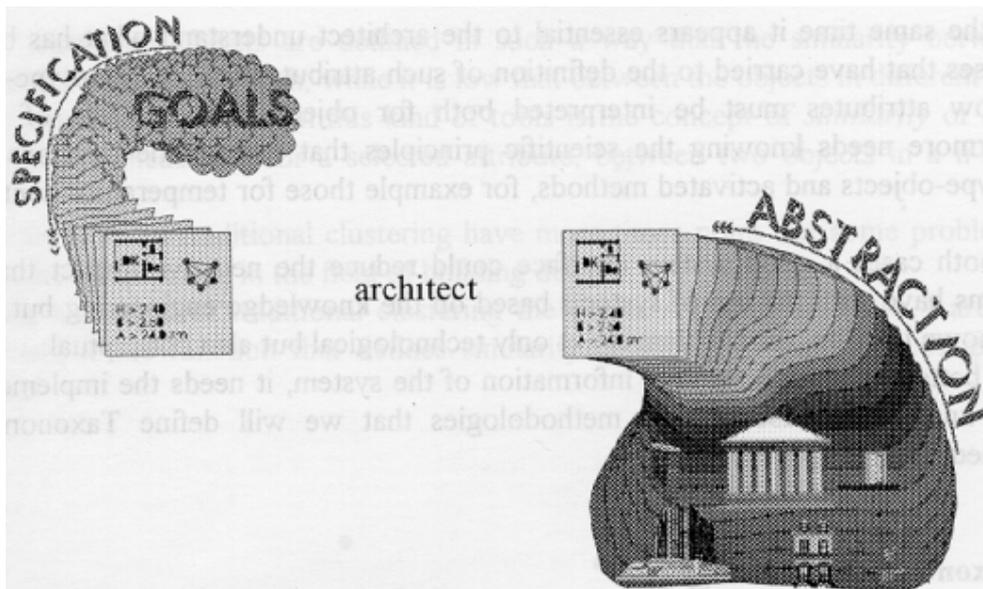


Figure 2 - The design process between abstraction and specification.

The experiences developed at CAAD Lab have shown that the number of the prototypes and the involved attributes, increases quickly and it is hard for the architect to understand the useful information which the system could supply, in a given stage of design definition, in a given context of representation, and in a given moment of considered verification. At CAAD Lab has carried out the design of a ward for infectious illness of 40 bedrooms of an hospital, constituted by 7,483 instance-objects, derived from the corresponding knowledge base, implemented with about 300 prototype-objects, see figure 3.

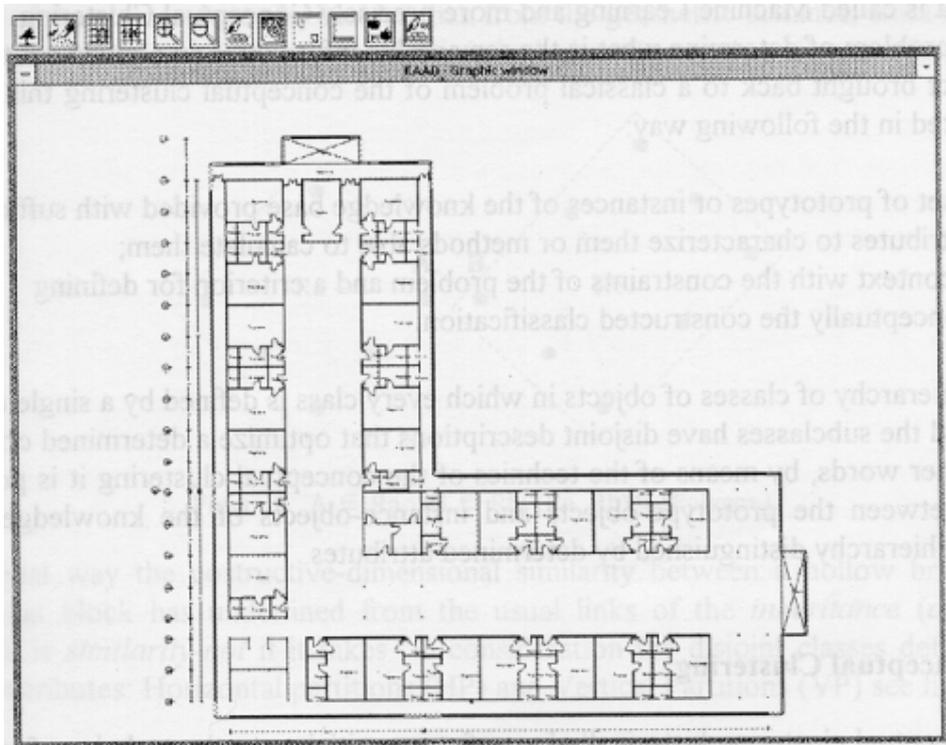


Figure 3 - Hospital designed by KAAD system

At the same time it appears essential to the architect understand what has been the processes that have carried to the definition of such attributes for the prototype-objects, and how attributes must be interpreted both for objects and for sets of objects. Furthermore needs knowing the scientific principles that explain the relations among prototype-objects and activated methods, for example those for temperature control of a room.

In both cases a good system interface could reduce the negative impact that these problems have with the use of systems based on the knowledge engineering but, as will have shown later on, the problem is not only technological but also conceptual. For better navigation through information of the system, it needs the implementation in the knowledge base of two methodologies that we will define Taxonomic and Multimedia.

The taxonomic methodology

The KAAD system (see Carrara G. et alii in references) keeps constantly up-to-date the representation of the *context* in which the architect works: the type of building that it has been defining respect to a determined prototype (adopted in preliminary phase); the scale; the objects defined; the objects undefined; the active constraints; the satisfied constraints; etc.

Every moment of the design iter, for the architect is important to recognize what is, with regards to the active *context*, the remarkable information, which could contribute to suggest solutions.

This task is worked out by the Taxonomic Agencies (TA) that are currently in course of definition, on the base of the experiences carried on different centers of research in the field that is called Machine Learning and more precisely Conceptual Clustering.

The problem of determine what is the remarkable information in a given context could be in fact brought back to a classical problem of the conceptual clustering this could be enunciated in the following way:

data:

- a set of prototypes or instances of the knowledge base provided with sufficient attributes to characterize them or methods able to calculate them;
- a context with the constraints of the problem and a criterion for defining conceptually the constructed classification. goal:
- hierarchy of classes of objects in which every class is defined by a single concept and the subclasses have disjoint descriptions that optimize a determined criterion.

In other words, by means of the technics of the conceptual clustering it is possible to define between the prototype-objects and instance-objects of the knowledges base a different hierarchy distinguished by determined attributes.

The Conceptual Clustering

The conceptual clustering historically bears from a criticism to the technics of traditional clustering that from time has faced the problem of the classification of objects.

The classes of objects are defined in such a way that the similarity between the objects of a class is very high, while it is low that between the objects in different classes.

The fundamental notion in this kind of tools is the concept of *similarity* or *distance* that it can be measured, for a selected attribute, between two objects in a n-attribute space.

The technics of traditional clustering have more times point out some problems that don't make them usable in the field of building design.

Using a method of traditional clustering the points A and B of figure 4 are in the same class if the function that defines similarity

is based on a measure of geometric distance.

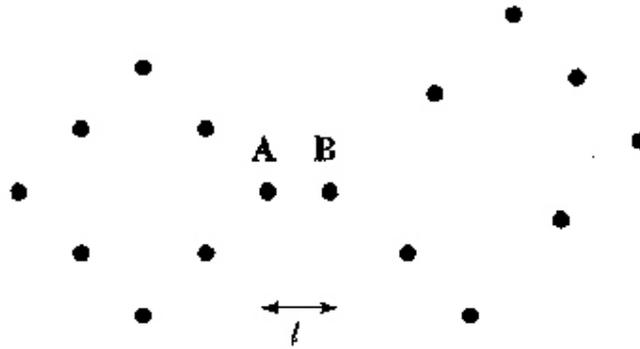


Figura 4 - $A, B \in L = \{\text{set of points that distance not more than } l\}$

In substitution of the concept of *similarity* any authors propose the concept of *Conceptual Cohesion*.

The two points shown in the figure 5 A and B are in two rectangles, Ra and Rb, if the creation of the classes depends, besides than from the geometric distance, from concepts, like the set of the polygons among which it is inclusive the concept of rectangle.

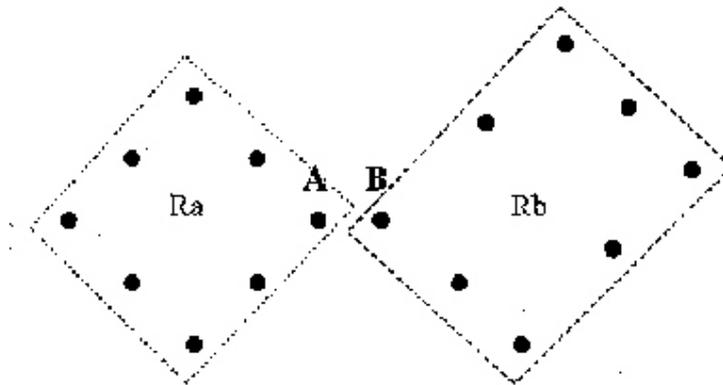


Figura 5. $A \in Ra ; B \in Rb ; (Ra, Rb) \in \{\text{Polygon}\}$

In equal way the constructive-dimensional similarity between a hollow brick and a hollow fiat block has underlined from the usual links of the *inheritance (a-kind-of)*, instead it is *similarity-not* if it takes in consideration the disjoint classes defined from *part-of* attributes: Horizontal partitions (HP) and Vertical Partitions (VP) see figure 6.

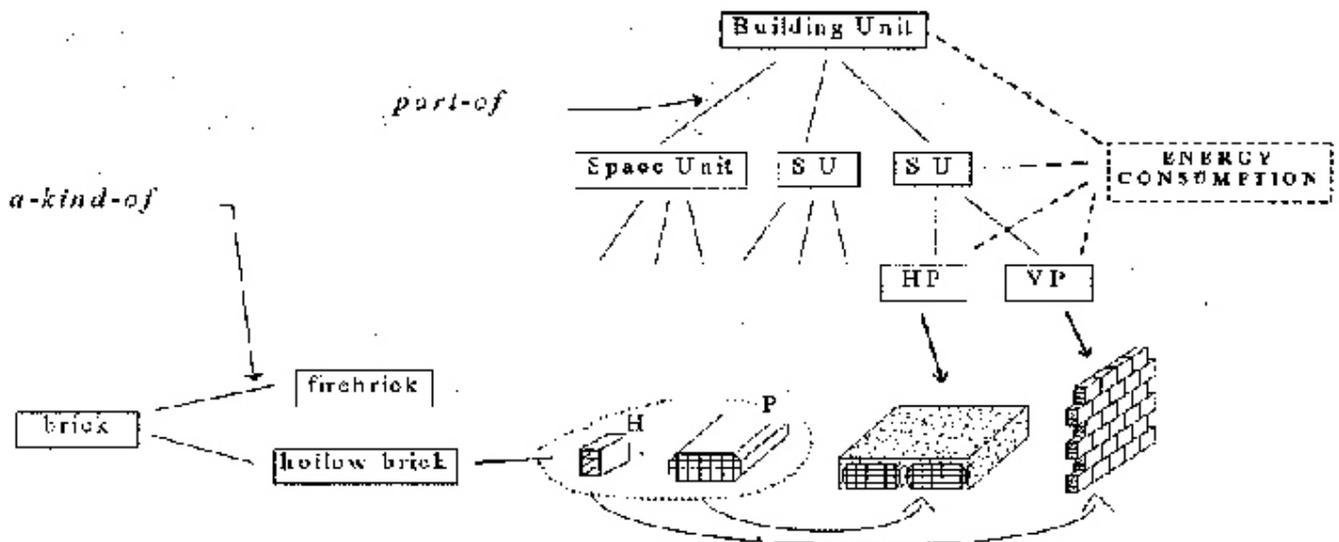


Figure 6 - The conceptual clustering.

The conceptual cohesion with *part-of* attribute between hollow brick (H) and hollow fiat block (P) could be symbolized like:

$$f(H,P) = g(H, P, \text{part-of}, L) (1)$$

As the measure of the similarity between two objects is essentially numerical, the resultant classes are often of difficult interpretation, see figure 7.

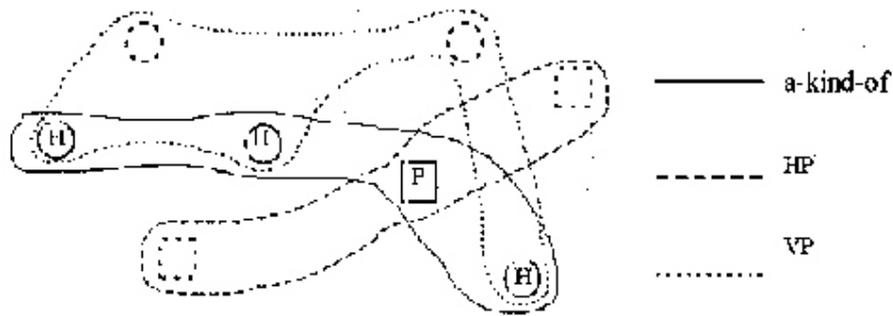


Figura 7 - Example of conceptual cohesion (1).

Moreover in the definition of the classes, the attributes of the objects have the same weight so that becomes necessary to structure the attributes in classes in order to understand what are the more remarkable attributes.

The measure of the similarity between two individual objects is essentially independent from the *context* and descends only from the properties of the examined objects even if different authors have introduced methods considering boundary information. The similarity among classes of objects, more precisely between classes of concepts of attribute of the objects is on the contrary strongly affected from the *context*.

To point that the attributes could define other hierarchies of new conceptual clusters, transversal to those more known of the common knowledge bases (part of \Leftrightarrow whole and a-kind-of \Leftrightarrow hierarchy) it is necessary include other attributes in the prototype-objects to allow a higher level of designing, or of abstraction.

In fact the architect is accustomed to modeling the building in function of global goal, like could be the temperature control of building. These checks presuppose other hierarchies, inferences, procedures on the same semi-lattice that represents the building model.

The multimedia methodology

The development of algorithms and methods able to establish, on demand of architect, a taxonomy among prototypes and instances in the knowledge base, allows to understand what is the correlate information with the particular design stage and, at the same time, allows architect to organize the information according to his conceptions.

The information that these types of algorithms process is still necessarily in form of attributes, variables and relationships that are efficient from the computational point of view, but a little explanatory for the architect.

As observed in the precedent sections, the use of a knowledge base requires that the choices that have been effected from others could be fully explicit to the architect.

To this aim it has been defined and it is in course of implementation a series of algorithms able to manage a multimedia representation *additive and hierarchical* of the information contained in the knowledge base.

It has been made a choice of multimedia description of the objects contained in the knowledge base and of the attributes of these objects. Different objects, that belong even to different classes of prototypes, could have attributes belong to a same class of an other hierarchy.

Therefore appear two levels transversal between them on which insert the multimedia format information.

first level is that of the prototypes. Can be be explicited the reasons that have caused the definition of the considered prototype and the aspects that characterize the class of objects with which it links. This kind of multimedia representation of the prototypes has realized hierarchically so that each levels of the hierarchy constitutes an further specification of the prototypes with respect to upper level. When the architect gains access to the information contained in a generic prototype will find, together to the information that characterize it, also the links toward the multimedia information of the more specific prototype-objects linked to it by the links *a-kind-of*. The architect could navigate on the net of the links up to the level of definition that he desires.

A second levels, transversal to the first, it is that of the attributes. These, if belong to the same class, must have the same multimedia information. If the architect requires information to the attribute "wrinkledness of a material" the system, from any prototype that has this attribute, must gain access to the same information that, clearly, it won't have duplicated everywhere the attribute exists, but will have linked up to hit from right link that determines the transversal hierarchy to the hierarchy of the prototype-objects (a-kind-of relationships).

At level of Functional Element (a door, a vertical partition, etc.) it will be show further the geometric and functional characteristics, also the thermal physical properties, the characteristics of connection, and even a film explanatory of the assemblage sequences.

At level of global goal for the temperature control could be useful a representation of the whole building that highlights the thermal bridges, or shows a histogram of monthly consumptions.

It is opportune to remember that with respect to the level of specification that the project has reached (preliminary or executive), the same design goal will activate different methods (approximate or analytical), and different representations (iconic or analytical).

Conclusions

The exchange of information between the software systems (knowledge bases, interfaces, and representations) on the one hand, and the architect on the other hand, it is a critical point of the CAAD.

While the integration of multimedia techniques and of conceptual clustering in the traditional computer program of CAAD already allows a user friendly interface computer \rightarrow architect, the problem of the machine learning is yet unsolved. Probably in

future the multimedia will be used to facilitate the implementation of the knowledge bases directly, architect → computer without software experts.

Acknowledgments

The Research activity has been financed by CNR (the Italian National Council for Researches), Progetto Finalizzato Edilizia.

References

Archea, J. 1987. "Puzzle-making: What Architects Do When No One is Looking.", in Y.E. Kalay (ed.), *Computability of Design*. Wiley Interscience, New York.

Carrara, G, and Y.E. Kalay (eds.), 1994. *Knowledge-Based Computer-Aided Architectural Design*. Elsevier Science B.V., Amsterdam, NL.

Carrara G., Y.E. Kalay, and G. Novembri. 1994. "Knowledge-based Computational Support for Architectural Design." *Automation in Construction*, no. 2-3, Elsevier.

Carrara G., Y.E. Kalay, and G. Novembri. 1992. "Multimodal Representation of Design Knowledge." *Automation in Construction*, no. 2, Elsevier.

Carrara G., and G. Novembri. 1992. "A Knowledge-Based System Concieved to be an Architect's Partner in Creative Design.", *CIB 92 World Building Congress*, may 12/14 1992, Montreal, Quebec, Canada.

Simon, H.A. 1984. "Why should Machines Learn '?" , in R.S. Michalski, J.G. Carbonell, and T.M. Mitchell (eds.). *Alachine Learning. An Artificial Intelligence Approach*. Springer-Verlag, New York.

Michalski, R.S., and Stepp, R.E. 1984. "Learning from Observation: Conceptual Clustering", in R.S. Michalski, J.G. Carbonell, and T.M. Mitchell (eds.), *Machine Learning. An Artificial Intelligence Approach*. Springer-Verlag, New York.

Schmitt, G. 1993. "Virtual Reality in Architecture", in N. Magnenat Thalmann, and D. Thalmann (eds.), *Virtual Worlds and Multimedia*. John Wiley k Sons Ltd., England.