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ACTIVITY KNOWLEDGE BASED SYSTEM: A DESIGN TOOL

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ABSTRACT

Architects use many sources of knowledge to solve design problems. The paper addresses the issue of computer aided architectural design by using Artificial Intelligence (AI) systems from a view of design, decision model, knowledge, and their relevance during the design process The study reviews the joint field of AI and architecture. Identify our view and representation of knowledge by an approach that may help describing architectural spaces.

This paper suggests a way to the representation of knowledge used by architects, that may help in reducing the redundancy of information, and can be used for the description of spaces in multiple building types.

KEYWORDS

Artificial Intelligence (AI), Knowledge based systems (KBs), Cognition, Models, CAD.

INTRODUCTION

The architect's major role is the creation and development of a design. With the aim of enhancing this role, architectural researchers have tried to grasp the essence of architectural design, and ways to design better (methods) and faster (using computers).

Computer systems have been put to a variety of different applications, each exploiting somewhat different aspects of the computer capabilities, such as; numerical computation, statistical and business data processing, data analysis, person - machine systems (interactive computer systems), process control or "command and control" systems, computer graphics and image processing, Computer Aided Design CAD, and Artificial intelligence [1].

CAD development started in the early 1960's, by the late 1960's computer-aided design has been increasingly employed in various aspects of mechanical, civil, electrical, chemical, and industrial engineering. Relating the problem of Architectural design, with the capabilities of computers programs and their wide applications.

Architectural design is an area of human experience, skill and understanding that reflects man's concern with the material culture and with making and doing; that is with appreciation and adaptation of his surroundings in the light of his material and spiritual needs. In particular, though not exclusively, it relates with configuration, composition, meaning, value and purpose in man made phenomena [2]. Design has long resisted definition because of its unpredictable and intangible character, marked by moments of insight, imagination and "flights of fancy" [3].

Discussing the nature of design in architecture Kim [4] stated that, the core of our work is designing i.e. the intellectual process working toward finding the potential solutions to a certain problem. This process is entirely internal, and the product, called idea, which is invisible. Secondly, is the externalization of the idea, i.e. making the idea visible, usually the product is called a plan. Lastly, to execute the plan, i.e. materialize the idea into a real thing, which is really not in the domain of the design proper .

Defining the problem of design to be associated with computers. As the design idea is well formulated, it's mere externalization and materialization is not a problem. Since; externalization can be carried out by anyone or thing capable of doing it, in strict compliance with the predefined area. Such as the drafting capabilities of a plotter headed by a computer. So the question is not of instructing the computer to formulate a well defined area, but of how to instruct the computer to create the data basis necessary to formulate a design idea.

- So, although computers can aid designers in many ways; store and retrieve data describing a design, automatically generate solutions to well defined problems, test potential solutions, it cannot design on its own [5].

Architectural design is considered to be an ill defined problem, as opposed to well defined problems [6]. With the difficulties in computing the whole process, attempts were made to create aids limited to specific design applications. Finally, computer aided drafting and modeling, came to dominate the field as a direct form of computer aid to design. From the previous review one can see hopes degraded by the enormousness of the design problems. The question is encompassed within the properties of traditional computing, "ill defined" nature of design problems, and our view of design.

KNOWLEDGE BASED APPROACH TO DESIGN

This section, at first discusses a view of design that can be represented within AI applications, and the foundations of AI. Secondly identifies the role of human designers and computers, and review a design decision model suitable for these roles.

Architectural Design

It is generally agreed that design is a complex and purposeful activity, undertaken when the means to achieve some task or desired *state* that is not immediately clear.

1) Design involves a conscious effort to arrive at a (state) of affairs in which certain characteristics are evident.
2) Design is also the process of originating systems and predicting how these systems will fulfill objectives.

3) The design is a (description) of the artifact from which predictions of performance can be made.

4) A design is therefore an abstraction, providing a (description) of an artifact that can be interpreted by some other agent for purposes of manufacture or construction [7].

- Therefore, the design process can be regarded as an exploration, inquiry, or search in a space of candidate design solutions, for one which meets the performance criteria of the searched for environment [8].

Artificial Intelligence

Artificial Intelligence can deal with ill-defined problems such as design, since it utilizes heuristic problem solving techniques instead of algorithms in problem solving. It is worth noting that the term (Artificial intelligence) was disclaimed by Simon. His research group at the MIT preferred phrases like " complex information processing" or "simulation of cognitive processes" [9]. The seeds of AI stretch out within three grounds.

1) *Search oriented automated problem solving*; finds solutions to questions, by searching among alternative choices (a tree) and achieve the goal by means of a sequence of actions (a plan).

2) *Knowledge representation*; has become a key topic in AI in that, it organizes required information into a form such that other AI programs can readily access it for making decisions, planning, recognizing objects, and situations, analyzing scenes, drawing conclusions, and other cognitive functions.

3) *Computational Logic*; has been developed to determine (prove) if a given hypothesis (theorem) follows from a given set of premises [10].

- The three foundations of AI are complementary to each other, since *Search* among possible answers to a design problem of a desired state, can be *Represented* by objects and relations within a knowledge base, and can be validated or discredited by the *Logic* of a given hypothesis in the system.

The Complementary Role Of The Architect And The Computer

Discussing the role of the human designer and the computer in a design environment, quoting Coons [11]

> "The different powers of man and machine are complementary powers, cross fertilizing powers, mutually reinforcing powers. It is becoming increasingly clear that the combined intellectual potential of man and machine is greater than the sum of its parts."

To identify the role of each, the study will review decisions in design, which are crucial in directing the process, and a design decision model that fulfills this "complementary powers" of both man and computer.

> "A *decision* is a risk-taking selection among alternative actions. For a decision to be possible there must be more than one alternative available. The decision process is applied to a set of alternatives. These alternatives represent a set of possible *acts* which the decision maker may choose to make. The acts are supposed to be connected in some way to a set of possible *outcomes*. If there is a known deterministic between the *acts* and the *outcomes*, the problem will is one of *choice* not *chance*. If the decision maker knew which outcomes would occur with each act, he could choose the act which resulted in the outcome he most *valued*. The choice outcome reflects a *value* judgment .... " [12]

Decisions in design, are often influenced by different constraints. Constraints in design result generally from a required or desired relationship between two or more elements. These constraints are produced by different generators (legislator, user, client, and designer). Generators produce internal and external constraints.

Internal constraints are those imposed by the relationships between parts of the objects or system being designed. External constraints are those imposed when a relation is desired with something which exists outside the object or system being designed [13]. The designer's choices are clearly limited, when he is facing the legislator's constraints (internal and external). While his choices are nearly open ended at the other end of the spectrum when there is no constraints but himself.
Choices available to the designer are those that are constrained by his own cognition and perception of a design problem. These choices are influenced by his own education, experience, personal choice, tradition and design data available to him.

- Many of these issues affecting the designer's cognitive structure are knowledge based, i.e.. influenced by knowledge. Therefore, it is unquestionably wise, to couple between creative human designers with structured and related information (i.e.. knowledge) via an intelligent knowledge based system, which we will review in the following text.

Cognitive Model Of Design

Reviewing a design decision model that can pair the designer and computer in the same process, is the cognitive model of March (1976) - which he adapted after the American philosopher Pierce (1839-1914) - that is Production, Deduction, Induction (PDI).

Discussing issues of reasoning, *Deduction* or analytical reasoning is the application of a *rule* to a particular *case* to give a logically determined *result*. Pierce identified that there was another type of synthetic reasoning besides *Induction*, that is *Abduction*. Which he named Production.

Production or Abduction is the inference of the *case* from the *rule* and *result*.- Synthetic

Rule + Result = Case

"All the rings in this box are made of gold"+"This ring is made of gold"= "This ring is from that box"

Deduction is the inference of the *result* from the *rule* and *case*. - Analytical

Rule + Case = Result

"All the rings in this box are made of gold" +"This ring is from that box" = "This ring is made of gold"

Induction is the inference of the *rule* from the *case* and *results*.- Synthetic

Case + Result = Rule

"This ring is from that box"+"This ring is made of gold"= "All the rings in this box are made of gold"

Viewing the previous syllogism within the context of architectural design; the outcome of productive reasoning is a case which is called the design or *composition. The* outcome of deductive reasoning is a *decomposition* which comprises the characteristics of the design that emerge from analysis of the whole composition - the whole is not merely the sum of these characteristics. The outcome of inductive reasoning is a *supposition*, a working rule of some generality - that is an hypothesis in the scientific sense, and more loosely, an idea, a theory, or in the modern usage a model, a type [14].

Production: Data models - Describe - Design

Deduction: Design theories - Predicts - Performance

Induction: Design Characteristics - Evaluate - Suppositions

The design proceed in the following fashion;

01.1 From the preliminary statement of required characteristics and

01.2 a presupposition, or protomodel, we **produce**, or describe,
01.3 the first design proposal
02.1 From design suppositions and theory and
02.2 the first design proposal we **deduce**, or predict,
02.3 the expected performance characteristics.
03.1 From the performance characteristics and
03.2 the first design proposal we **induce**, or evaluate,
03.3 other design possibilities, or suppositions.
The cycle then begins again:
11.1 from a revised statement of characteristics and
11.2 further, or refined suppositions we **produce**
11.3 the second design proposal, and so on ...

"Design will remain more or less personalistic and a matter of opinion, albeit professional..."[15]

- The three modes of reasoning / thinking should be present in a design system to satisfy the previous design decision model. Creative humans use abductive reasoning, AI systems employ deductive reasoning, and traditional computers use inductive reasoning.

DESIGN SYSTEMS

The analogy between design and reasoning leads to viewing interpretation of design corresponding to logical deduction, while the translation of meaning into a design corresponds to the logical process of abduction. There are two types design of systems one that describes design and another that produce its form. Theoretically a comprehensive system will have the two types, refer to Fig. 1.

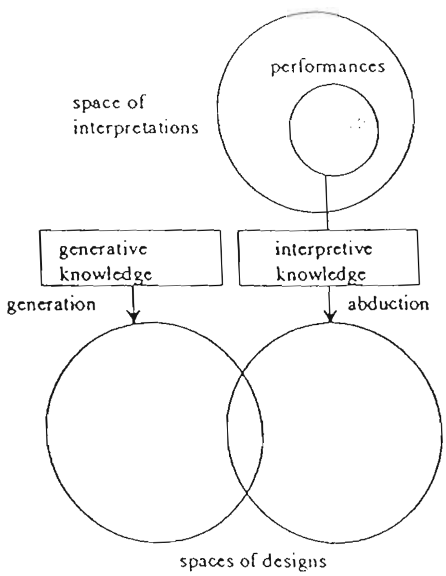

Fig. 1

Generative and interpretive knowledge serve to define spaces of designs. Given a set of performances, we wish to produce designs that fall within the intersection of the two spaces.

Source: (Coyne et al, 1990) p. 61

Interpretive Or Semantic System

An interpretive system infers the meaning of design, by mapping between some statements about design (its description) and certain performances (or interpretations or meanings). Taken that these statements about design and their meaning are analogous to a sentence in some language, it is the concern of semantics. The meanings of a design are simply the attributes of the artifact description that are not explicit in the description, but must be inferred in some way.

Generative Or Syntactic System

A generative system is concerned with the production of designs that conform with the rules that shape a correct sentence in a design language i.e. the syntax. A syntactic system serves to define a space of designs (the designs in a language made possible by its grammars).

Table 1 in Appendix A-summarizes the major characteristics of design systems and their tools.

- From the previous review of design, knowledge based design systems, and their tools, it may be noted that to build a complete design system it must comprise; both types of systems, i.e. interpretive systems and generative systems. All together with an architect they may complete all the modes of reasoning required in the process of design. It may also be noted that for such a system to exist, it must have a tremendous amount of structured knowledge, that is concerned with interpretation and generation, which can be built gradually by time.

To build a multitude of knowledge bases related together to fulfill different aspects of design knowledge, requires control both from the inside of the system and the outside (designer). Issues of control from the inside can be the rules that are built within the system to describe different hierarchies of knowledge and their importance to a design. Other control issue may be the way knowledge is structured and related. Relating to the latter issue of control, key knowledge about design is required for a system to be useful in a variety of different building types.

ACTIVITY KNOWLEDGE BASED SYSTEM - Proposed Approach

A proposed approach for an interpretive knowledge based system that might prove to be useful in the design of different building types, since it relies on a general key issue of space design i.e. "Activities".

Activities are the things people do - the defined, physical interaction between a person and an environmental cue. Cues tell people what activities should occur in a space. Different types of furniture and equipment will identify the activities each room was designed for. Activity sets are groups of activities that will occur together. These groups may be activities that serve the same purpose, or they may be made of one centrally important activity and those activities that support it [16].

Recorded design data, in most cases if not all manual hand books i.e. (Time Saver Standards for Architectural Data, Graphic Standards, etc.) are intended to help designer understand the some of the constraints of design, both internal and external . Most data books, have the tendency to repeat knowledge they present regarding the activities within a building, as they are categorized according to building types. Other critique is that they are highly ethnocentric [17], for they tend to address people with certain cultures.

With these points in mind, it was thought that using "Activities" i.e.. (sleeping, washing, learning, entertaining ..etc.) as a foundation for the Classification of knowledge, may be helpful in three ways:

1) Reduce the redundancy of knowledge found in design data books (economy of thought), as the design information is composed to fit the situation the designer is handling at the present time.
2) Help designers to design for a different culture, since the knowledge is about the activity and its proper environment, is not exclusively spatial data, information about the users can be induced as variable attributes from project to project.
3) Designers and Systems supported by Activity Knowledge bases can use it in the design of different building types using the same activities.

System Description

Fig. 2 represents the schematic diagram for a proposed system that is composed of multiple Knowledge bases (KBs). These KBs are working under an operating expert system and a designer.

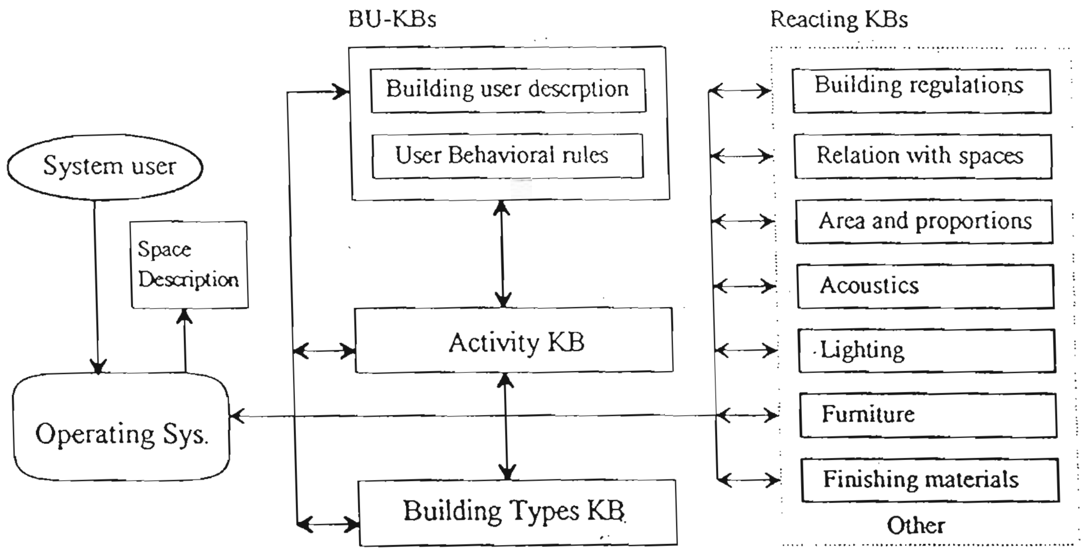

Fig. 2 Activity Knowledge based system

The Operating System controls all the KBs and regulates the processing of information between different knowledge bases. It also helps the designer to ask the right questions and in the right form so that the system could answer him. Also to formulate the evolving space description in an understandable manner (graphical construction or text).

The designer takes decisions regarding the evolving Space description, whether to implement it, or to modify the description.

There are four major groups of Knowledge Bases; 1) Building User, 2) Activities, 3) Building Types, and 4) Reacting KBs.

1) Building User Knowledge Bases (BU-KBs)

Recorded data usually have a high amount of determinism. In an effort to reduce this determinism, knowledge of the building user is entered via a knowledge acquisition module of the operating system.

The major function of these KBs is to map the user's preferences, ways of doing things with the ACTIVITIES KBs. Preferences may differ greatly from culture to another, many factors may be considered, such as area preferences, it may be noted that an area may be sufficient for a certain activity to take place, but yet it is not satisfactory for the user. Many variables affect the environmental design to afford a specific behavior. One set is concerned with the specific actions and movement patterns of the individuals or people involved, and another is concerned with psychological needs such as privacy, personal space and territorial control. The first set will be of concern to "Building user Description KB" and the second will be the concern of the "Behavioral Rules KB".

The (BU-KBs) deal with the designer through the Operating System. As an external KB the user of the system may alter existing KB with new factors of different users.

Interactions between the two BU-KBs (Users description and Behavioral rules) with each other and with Activity Knowledge Base.

Reviewing the validity of such an approach, by examining a cross culture example. Eating habits of people at a restaurant may differ slightly than those at home if they are a *Western* culture, however the habits change grossly if they are from *Oriental* cultures and eating at "Home".

A completely different setting of the environment for eating is required, since they are going to sit on the floor and either eat a roasted lamb with rise or Sushi with rise. The setting may change from the floor finishing, to the level of lighting at the floor, ...

2) Activities Knowledge Base (ACT-KB)

The Activity KB maps between the activity taking place, other activities (sets), and the effective environment within a building type. Activities will probably be represented as facts made of objects and their relations, knowledge and control information. Facts about activities, such as basic requirements to do an activity, possible locations within buildings types, users influences on activity and sets of activities.

Knowledge statements about facts inferred from (BU-KBs) and new inferred facts from ACT-KB, such as - **IF** *(user) is an (oriental)* **AND** *(eating) at (home)* **THEN** *(arrange) for (floor furnishing)* **AND** .....*etc.* Control information such as the implications of the new facts *(floor furnishing)* and its relations with the Reacting KBs for instance floor finishing. The activity KB will communicate internally with all the system components via the operating system.

3) Building Types (BT-KBs)

Map activities within spaces (Dining room, Class room, etc.) of a building type (house, school) and relate spaces together. The knowledge base acts as a filter to select the appropriate attributes of the space from the Reacting KBs.

The building type KB takes inferred facts from the activity KB and relate these facts with spaces and their attribute found in the reacting KB. Coupling between building types and activities. The BT-KB takes input from ACT-KB as mentioned, and selects matching information from the reacting KB via the operating system.

4) Reacting KBs

Acts as a knowledge bank, that interact with the Activity KB, Building Types KB, and the System user via the operating system.

These are specialized KBs that render to the system, specific information about the housing of an activity within a building type. Being a multitude of information sources, acting under the request of several Knowledge bases, there are priorities among these sources (about which is more important to a specific situation). Operating under the guidance of the built-in rule, the operating system and the designer, would solve the problem.

CONCLUSION

For the last ten years or so, there was a continuos effort from researchers with an architectural background to introduce AI applications to architectural design problems.

Some directions of such research work are;

- Knowledge based design systems
- Shape Grammars
- Integration of natural language and graphics
- Design interfaces and man/machine interaction
- Computer simulation
- Graphics and Graphical programming environments
- Spatial Algorithms
- Object oriented information models

and others ...

Most of these directions if not all are still under investigation, and there are no clear evidence that any of these directions is not facing obstacles. AI application is a relatively new computer science issue, and the search for new directions and approaches is still the core interest of most schools of architecture.

This paper introduced an approach for a Semantic knowledge Based Design system that is still under research. The Activity Knowledge based system, is a system intended to describe building spaces. Overcoming some obstacles of previous efforts to describe buildings, because of;

1. Its general use regarding building types, and reduction of information redundancy.
2. Specific use regarding (Users) and how they will perform activities (lack of determinism).
3. Power in dominating the search for knowledge in different KBs.

The system core knowledge base is a general and important element, that shapes and constrains the surrounding environment to be designed, that is "Activity". Activities relate different people to a space to be designed for them, so it was meaningful to integrate a user description KB to the system. Basic activities and their sets occur within different building types with slight variations. Building types are their spaces have their own constraints and rules. Activity KB and the Building types KB extracts different requirements (for the space description) from the Reacting KBs (specific areas of knowledge). Working together under an expert system shell and designer - the proposed system may prove to be a powerful design tool that assists in decision making.

APPENDIX - A

Table 1. Knowledge based Design systems Summary

System	Paradigm	Computational representation	Tools
Interpretive	Goal Directed[1]	Backward search, begins with a statement that constitutes an interpretation of the design and attempt to determine whether it is true or not.	- Deterministic knowledge, for certain domains and for certain formulations of the design task, it can be assumed that there is a direct mapping between design requirements and the design description resulting from these requirements - Fuzzy Logic, stating design knowledge in probabilistic terms in order to decide among competing design descriptions. - Constraints, reasoning from the constraints within our design knowledge to produce new design constraints, that may be more effective in defining design possibilities. - "Truth Maintenance", directly settling the conflicts among competing decisions.
Generative	Data Directed[2]	Forward search, begins with a set of facts about the design that are already known and asks what can be inferred from these facts.	- Grammar Rules a) information processing; defines the description language to which statements must conform. b) vocabularies: How design elements are configured - Generic descriptions of designs (prototypes), a prototype signifies a description of a class of generalized designs that embeds a notion of the design description to be produced. - Design generators, the space of designs is defined by means of some algorithm that produces all the designs - all the possible configurations of elements - in that space.

notes:
1 This paradigm assumes that the characteristics of the desired solution (in terms of its objectives and constraints) can be formulated independently and prior to engaging in the process of seeking a solution that meets them.
2 Opposite to the previous paradigm, the search process itself shapes the criteria by which the solution is judged, therefore design is a process of discovery, which generates insights to the problem that were not previously known. This paradigm relies on precedents, symbols, and metaphors for guidance.
Both Goal oriented and Data oriented rely on mapping from precedents; the first as an analytic means, which draws on experience, and the second as a synthetic means, which simulates discovery.

Adapted from: 1) Kalay et al., 1990 2) Coyne et al., 1990

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5] MITCHELL (op. cit., pp. 58-62).

6] Although the concept of ill-defined problem is not in it self very well defined, it is possible to identify some typical characteristics;

- No complete and definitive formulation is "given" at the outset. As it must be extracted out from a tangled, and information-rich context.

- No applicable model is provided; as the problem solver must define variables and operations which establish an appropriate set of potential solutions, which is also hard to grantee.

- The formulation which is achieved is not rigorous; the set of potential solutions to be explored and the solution criteria may be informally characterized.

- The formulation does not remain stable; conditions and criteria may alter as the design process progress.

- The formulation may embody conflicts and inconsistencies which must be resolved during the course of the design process.

- The problem solver does not have all proper information available for considerations at any one time; potential solutions may be overlooked or forgotten, and different subsets of potential solutions and criteria may be discovered or retrieved from memory at different stages in the design process.

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