The S:ITEC Model. An integrated system of treatment of data and knowledge in construction.

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Abstract

Recently, in the field of Computer Aided Design (CAD), notable efforts have been made with theoretical results largely unproven due mainly to the difficulties of the large scale production required. On the other hand, other applications of an excessively practical nature have been developed which, however, present a high degree of difficulty in bringing about their integration.

In the first case we would include, for example, representational Models and Classification Systems and in the second case the various CAD systems as well as the partial integration work carried out although often at a high level of specialization.

This work means that, although each time we get nearer to reaching the goal where all these efforts would coincide, no concrete system adaptable to the majority of models proposed has really yet been put forward or used for the various applications developed.

A system which would meet these needs must do so in a single, integral manner (which even could be standardized in the most universal way possible) so that finally the user could at any moment control in real time each and every one of the various decisions which must be taken along the difficult design path, understood as the process of conception.

In order to achieve these objectives, what becomes fundamental is the adequate treatment of the various methods and elements on which we depend, in order to carry out our task so that, in some way or other, we can simplify and reduce them to two single elements: Data and Knowledge. While it is certain that in the first case there is almost complete coincidence among most of the existing proposals in various parts of the world, in the second case there exists a wide range of approaches as well as a relative lack of concretion.

The SITEC model (Integrated System for Treatment of Construction Elements), a research project being developed by the Catalan Institute of Construction Technology, is shown to be capable of providing the necessary integration of the two major groups: Data and Knowledge, not only as a representational model but as an expert and consultative system for making decisions and carrying out the checks constantly required in construction design which may be carried out by computer.

Introduction - Design in Construction

In the field of Computer Aided Design in architecture and civil engineering, or simply, in construction, a number of concepts have been used which are more or less accepted by most research institutions, researchers and research and development companies although

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perhaps they have not always been rigorously defined. Consequently they have been applied in different ways according to the case at hand.

Some of these concepts are: data, knowledge, objects, classes, attributes, properties, values, relations, rules, representational models, etc. It is difficult to be specific about the significance of each of these concepts without having a common reference in which to place them correctly. For this reason, we propose to make a schematic arrangement of the general process of Computer Aided Design along the lines indicated (Figure 1).

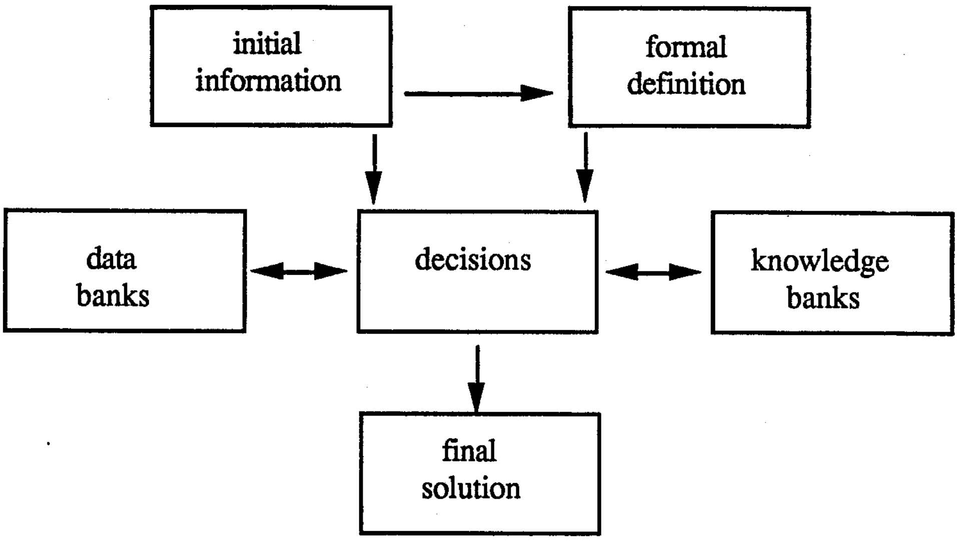

Figure 1

INITIAL INFORMATION: This represents all the information necessary in order to set out the design problem. Belonging under this heading, for example, would be the definition of the land, the parameters of the development, information about climatic conditions, etc.

FORMAL DEFINITION: Beginning with the initial information it is necessary to set out a formal definition of the structure proposed, that is to say, a topological and geometrical diagram of a general nature upon which it is required to define successive components in accordance with a certain strategy.

DATA BANKS: In order to define successive components we can make use, by way of reference, of the information provided by the various Data Banks. As a result there can be side-by-side Data Banks covering different aspects of construction such as materials, products, procedures, manufacturers, etc.

DECISIONS: Simply put, these can be defined as the process of acquisition of each of the different pieces of data selected from existing Data Banks and provisionally or definitively incorporated in the formal definition of the structure in its progress toward the ultimate object of the design.

KNOWLEDGE BANKS: Under this denomination the object is to represent every imaginable consideration which, in one way or another, may affect the acquisition of data in the process of decision making. If it should be necessary to carry out certain checks (stability, hygrothermal behaviour, etc.) at any moment in the design process, the existence of Knowledge Banks will be of great assistance.

FINAL SOLUTION: This refers to the final result achieved once all decisions have been taken and all checks carried out independent of the model selected.

Data and Knowledge - Simplified Scheme

Independently of the representational models, it is possible to make a relevant abstraction if we imagine any structure as a list of "items" with a concrete value or "unit of data" for each of these items. Evidently, the list may reach spectacular dimensions and may not be the easiest way to solve the problem although the idea allows us to make a simplification which helps to clarify the differences and consequences for design between "Data" and "Knowledge".

We can therefore imagine that we are able to establish a general model for construction consisting of a list of items which from here on we shall call "Properties" (P) and for each of these a list or definition of all its possible "Values" (V). Evidently, in this idealized representation all kinds of data will be mixed together, subject, in practice, to specialized processing (Figure 2.1).

Starting out from this general model, and in accordance with the concrete needs of each case, we could draw a particular model without involving any procedure other than the selection of the relevant "Properties" applicable to our case. As a result the particular model would be smaller than the general model (Figure 2.2).

Finally, it is necessary to assign a "Value" to each "Property" in order to obtain a solution to the design problem initially set out (Figure 2.3).

P1	P2	P3	...	P M
V1	V1	V1	...	V1
V2	V2	V2	...	V2
V3	V3	V3	...	V3
.	.	.	...	.
.	.	.	...	.
Vn	Vn	Vn	...	Vn

General Model

Figure 2.1

P1	P3	Pg	...	P i
V1	V1	V1	...	V1
V2	V2	V2	...	V2
V3	V3	V3	...	V3
.	.	.	...	.
.	.	.	...	.
Vn	Vn	Vn	...	Vn

Particular Model

Figure 2.2

P1	P3	Pg	...	Pi
	XX			
XX				
				XX
		XX		

Solution

Figure 2.3

The **general model** is no more than a "Data bank" which at any moment can provide us with any information concerning one aspect of construction. The **particular model** is a concretion of the general model and is therefore also a particular "Data bank", which as a result is smaller in size, and the **solution** is a possible representational model of the proposed structure.

In view of this simplification we are able to propose a way of defining Knowledge according to the concept of "Data", made up of the binomial "Property"/"Value" in the following fashion:

"A UNIT OF KNOWLEDGE IS ANY GENERIC RELATION BETWEEN TWO OR MORE UNITS OF DATA"

As a result, it would seem difficult to propose a "Knowledge bank" without knowing about the organization of the data which this knowledge connects, that is to say, without the corresponding "Data bank". It is on this premise, and only so, that we are able to advance in our understanding and proper processing of Knowledge in order to be able to use it in construction through Computer Aided Design.

It is for this reason that we here propose the SITEC model as an example and proposed method for the integration of "Data" and "Knowledge" aimed at better understanding and exemplification.

The SITEC Model - Integration of Data and Knowledge

SITEC (Integrated System for the Treatment of Construction Elements) is a project which has been under development at the Catalan Institute of Construction Technology since 1984. It is made up of two different parts: BEDEC (Structured Data Bank of Construction Elements) and BECOC (Structured Knowledge Bank of Construction Elements), that is to say data and knowledge are treated separately but only in terms of production given that the integration of these two parts is complete, as we shall soon see.

The SITEC model is made up of a hierarchical structure of 7 different levels of complexity from the smallest element or component to the most complex job or project (Figure 3).

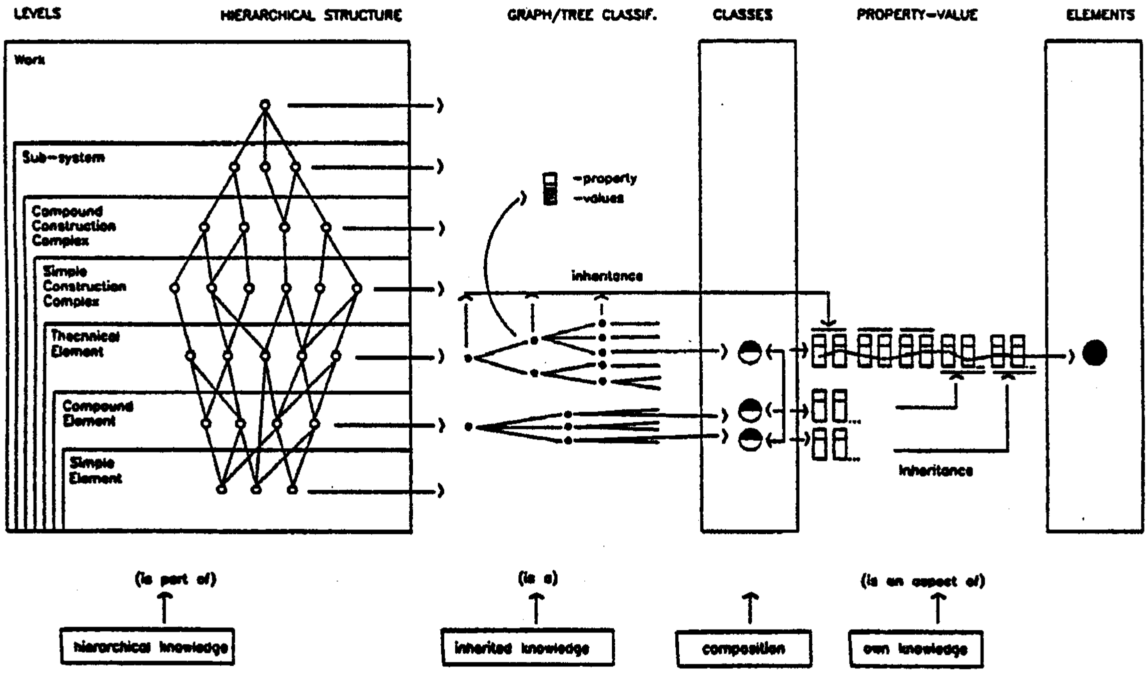

Figure 3

At each of the seven levels a system of rational path based on "items" is established which makes it possible to finally arrive at a concrete "class" of elements. In fact, we believe that any system of classification should be able to serve for this purpose. As a result, we prefer to think of this access system as a "graph" model rather than a "tree" model with the object of making possible the necessary connections according to the classification system employed. What is important in any case is that the final "class" is in perfect correspondence independently of the path taken to get there.

In each "class" we establish a list of "properties" and possible "values" for each one of these so that each combination of values, through each property, perfectly determines and defines a different construction element.

We should make it clear that it is equally possible to establish "properties" at a level higher than "class", that is to say at any point (or item) in the path system or classification graph with the particular quality that it may be inherited by any "class" which can be reached passing through that point.

At the same time it is should be mentioned that, if an element at a determined level is made up hierarchically of elements from lower levels, it cannot be completely defined until each and every one of its components have been defined. As a consequence there is also a hierarchical inheritance of properties.

We can easily show that this model includes or is in accordance with the most fundamental features offered by the more significant models which have been developed and accepted to date.

Specifically, the relation "**is part of**" is represented in the hierarchical structure, the relation "**is a**" is to be found in the path system or classification graph at each level, while the relation "**is an aspect of**" is to be found in the list of properties and in any representational model.

It should be noted that, without wishing to do so, we have already established units of knowledge by the simple fact of having established relations between data as we had defined earlier. In this case, however, we can consider these units of knowledge as structural and, as a result, more linked to the proposed organization or model in each case than to the science of construction.

Having attained these premises, we can now establish the different types of knowledge which must be considered and plan their treatment and organization in order to guarantee a structure compatible with data already known.

To give an idea, we might classify construction knowledge in two ways: according to its typology and according to its function.

Classification according to typology would include:

BOOLEAN KNOWLEDGE: This consists of knowledge which can be expressed as an IF-THEN clause -- IF (Condition) THEN (Conclusion) --imposing restrictions or conditions on possible values of the related characteristics for the unit of knowledge in question. For example: IF (Material) = Ceramics THEN (Colour) = Red

FORMULA TYPE KNOWLEDGE: This consists of knowledge which can be expressed as a mathematical formula in which the assignment of the value of a determined property is clearly set out beginning with the values of other characteristics. For example: IF (Form)=Orthohedron THEN (Volume)=(Length)x(Width)x(Thickness)

MATHEMATICAL TYPE KNOWLEDGE: This consists of knowledge which can be expressed as a mathematical formula but without setting out any assigned value as it involves an implicit function. For example:

IF (Form)=Triangle THEN (Angle 1)+(Angle 2)+(Angle 3)=180°

According to their function, units of knowledge may be quite different and disperse but they can always be brought into correspondence with the properties and values which are related, always in accordance with the hierarchical structure of data employed. The following are examples:

GENERAL KNOWLEDGE: This covers general catalogue properties of a scientific nature and therefore not associated at any specific hierarchical level. In this case, the condition IF disappears because of its universal nature. For example: (Electrical potential) = (Power) x (Difference in Potential)

CLASS KNOWLEDGE: These are established exclusively between properties of a determined class and of any typology.

KNOWLEDGE BETWEEN CLASSES: These are established between properties of different classes and of any typology.

Treatment of Knowledge - State of the Art and Results of a Case Study

In practice, we shall come across knowledge of every typology and function implicit in the development of the three basic groups of methods which appear to be fundamental to the problem of Computer Aided Design: definition and representational models, data banks and specialized calculations for the resolution of more or less complex problems.

Definition and representational models require the incorporation of the knowledge necessary to guarantee the consistency of the information.

In data banks the existence of knowledge which may reduce the volume of information to be stored, such as parametrization, is received with notable satisfaction.

Finally, specialized calculations are no more than a succession of instructions and sequential algorithms, that is to say of knowledge of mathematical or formula type, inevitably necessary in order to carry out certain proofs based on initial information.

The treatment method proposed by the SITEC model is not different from this real situation and advocates the effective integration of data and knowledge under the same structure. It is this integration which must make possible the involvement of Expert Systems so far as knowledge is concerned as it has been for Relational Systems in the case of data. It is therefore a matter of maintaining interactive knowledge in a constant, unitary and dynamic form, integrated with data in order to achieve all of the objectives set out earlier.

In order to prove this statement, a prototype was implemented in order to resolve the design of the "skin" of buildings in accordance with thermal, acoustical, weight and economic requirements. As an application it combines the characteristic elements of Computer Aided Design: data bank, knowledge bank, graphic interface and user interface.

DATA BANK: We have used BEDEC (Structured Data Bank of Construction Elements) as the carrier for the information required and in accordance with the SITEC model for properties/values implemented on ORACLE. The data assembled make reference to the various elements of the building skin (facing, façades, doors and windows, external roofs and barriers between land and other buildings).

KNOWLEDGE BANK: We have used BECOC (Structured Knowledge Bank of Construction Elements) as the carrier for the knowledge required and in accordance with the SITEC model established for data which makes integration possible. Specifically, knowledge assembled is in accordance with Spain's regulations on thermal conditions (NBE CT-79), acoustical conditions (NBE CA-82) and gravitational effects (NBE AE-88).

Every condition, demand, clause, requirement or simply each definition has been expressed in accordance with the typology for knowledge set out, always with reference to the levels, headings, classes, properties, values, etc. established by BEDEC. As an expert system for the implementation of knowledge we have used the NEXPERT system.

GRAPHIC INTERFACE: A simple standard graphic system has been developed for formal definition and simulation of the building skin which is capable of providing the geometrical information necessary to activate knowledge at the successive stages of design decision.

USER INTERFACE: A WINDOWS system has been developed and the connection between all the systems has been programmed under language C.

Operation of the Prototype

Definition:

By means of the graphic interface the building to be designed is simulated purely at the "skin" level, that is to say without the need for excessively detailing the interior arrangement of the different spaces along with the services proper to this type of application. The example covers an office building.

Using a specific module we determine the environmental conditions, or preconditions, necessary to check the requirements and application of knowledge (Climatic zone, acoustical situation, etc.).

Assignment of Construction Solutions:

At will, and this is one of the basic differences from other applications involving knowledge which operate on the basis of making a "final choice", the user can select the type of element it is desired to define. It is from the moment of this selection that BEDEC moves into action and shows the different properties and possible values with complete respect for level hierarchy.

At this stage it is a matter of assigning a concrete and single element or construction solution from the data bank to each section or surface unit of the skin defined on the graphic interface.

Each time we define a value for a property, the BECOC system goes into action through units of knowledge applied to the corresponding property and, according to its corresponding dynamics, updates the possible values of the other properties, that these units of knowledge can continue to verify.

This process is repeated as often as desired until we arrive at an assignment which is complete and in accordance with our needs.

We should mention the following significant situations:

- Through the knowledge bank, the prototype at all times controls each of the decisions or selection of values made by the user.
- The consequences of each decision or selection of values is immediately reflected in all the other possible values. Units of knowledge convert the data banks into something dynamic instead of static.
- The system does not operate on the basis of being able to make a "final choice" but rather allows the making of an unlimited number of decisions or the selection of values as many times as is desired with the assurance that the consistency of existing data will be maintained at all times.
- At any moment it is possible to modify the initial formal definition. The system will update all the new values by applying suitable knowledge.
- Mathematical type knowledge, such as obtaining the overall thermal transfer coefficient (kg) of the building has not been optimized. That is to say, when a value related to this unit of knowledge is defined, the system verifies the existence of at least one solution with the rest of the updated values.
- The most significant values needed to verify the regulatory requirements are always updated and visible throughout the process. While at in-between moments this data may have no significance, on the other hand its dynamic nature serves as an auxiliary aid to decision making.

Conclusions

In view of the proven performance of the SITEC model through the prototype developed, it is possible to state the following conclusions:

- The treatment of knowledge must be very closely linked to that adopted for data given that a unit of knowledge is nothing more than a generic relation between two or more units of data.
- There are certain determinate units of knowledge which are structural and which vary according to the proposed representational model for data.
- Expert systems, understood as intelligent actions without function in a defined sequential order, are the immediate carrier of knowledge of all kinds through which we are able to make apparently static data banks dynamic.
- The SITEC model carries this integration of data and knowledge understood as a dynamic system to aid design rather than as a theoretical representational or definition model.
- Between the alternative of integrated systems and that corresponding to specialized systems with standardized interchange of data and knowledge, it is necessary for construction to choose the first, at least until a sufficiently accepted process of design has been defined with a clear specialization of tasks and a rigorous planning and execution of actions.

- Knowledge banks may be developed as such with the most appropriate classifications according to the particular situation. What becomes fundamental, however, is the association of each unit of knowledge with the levels, classes, properties, and values to which they are related.

- It is essential to continue research into the making of models for knowledge in order to carry over results to the various aspects of Computer Aided Design and to achieve real and effective integration of all the procedures involved to this task.

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