BECOC: A KNOWLEDGE BANK AND ITS USE IN CONSTRUCTION AND CAD SYSTEMS

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Abstract

The development of the BECOC prototype (Structured Knowledge Bank for Construction Elements) was undertaken in order to test the integration of Data and Knowledge using the SITEC model (Construction Tecnology Information System). After the graphical definition of a building exterior, the assignment of the construction solutions is dynamically controled using the Knowledge Bank for real time decision making.

To represent the knowledge that acts on the data the knowledge bank consists of an Object Oriented Data Base and a Rule System, developed using the NEXPERT/OBJECT package. In this manner it is possible to establish relationships among properties, concepts, restrictions in values, structural relations and the control of standards compliance, which in this case has been limited to thermic, acoustic and weight requirements.

The system helps the user to take decisions and it analyses the context in order to make the deductions needed to maintain internal data consistency. The positive results of this work indicate the way for further developments, and demonstrate that expert systems and traditional technologies coupled together can be effective and give the desired answers in monitoring design in the everyday problems in construction technology.

1. INTRODUCTION TO THE SITEC MODEL

During the last few years the "Institut de Tecnologia de la Construcció de Catalunya - ITEC" has been dedicated to the research and development of a construction elements representation model, the SITEC model (Construction Tecnology Information System). SITEC treats the construction elements in a hierarchical structure, whilst at the same time is capable to manage as well other information like concepts, properties, values, interrelations between properties, interrelations between structural elements, property value calculation formulae, rules etc (Fig. 1).

The object of SITEC is to integrate Data and Knowledge, understanding "knowledge" as "THE GENERIC RELATIONSHIP BETWEEN TWO OR MORE DATA".

SITEC is based on a hierarchical model structured in the following seven levels: Simple element, Composite element, Technical Element, Construction detail, Construction solution, Subsystem and Building (Fig. 1).

Vertically each level has a hierarchical relationship with the lower levels (a superior level is formed by a group of elements of the lower levels). Horizontally the concepts of each level may be subdivided into different specific classes (Fig. 1).

Given that one may arrive at the same element group by different routes through the system, it is necessary to clarify that the general relation existing in the structure appears to be more like a graph than a pure hierarchy.

For each general concept and for each specific class there are associated properties and values. A given combination of values, limited by any property restrictions or interdependencies which might exist, will give rise to a "closed construction element" (i.e. a construction element completely defined).

Bearing in mind that the hierarchical nature of the structure in which an element in a higher level depends on the elements in the lower level, it can be seen that a construction element in a level cannot be totally defined until the elements in the lower level are as well totally defined. In addition, the relationship between an element and its component parts establishes an inheritance of properties and values between "children" and "parent" elements.

Generally speaking, its possible to find three principal types of relationships:

- Structurally and between levels: " is a part of".
- Between concepts in the same level: " is a".
- Between properties and their corresponding class: "is an aspect of".

These relationships, and others, such as relationships between properties, form knowledge that can be translated into rules.

In the SITEC model the Data and the Knowledge are incorporated in the same single structure in such a way that the Knowledge maintains a constant dynamic control over the Data assuring thus its consistency.

In order to apply and demonstrate the SITEC model validity, the BECOC prototype has been developed. This prototype is a software application which integrates different technologies such as relational data bases, graphic modules, multi-window envirомment (XWINDOWS) together with Expert System technology.

The BECOC prototype is directed toward the design of building exteriors (coverings, primary and secondary finishings, open space roofs, interior

SITEC Model

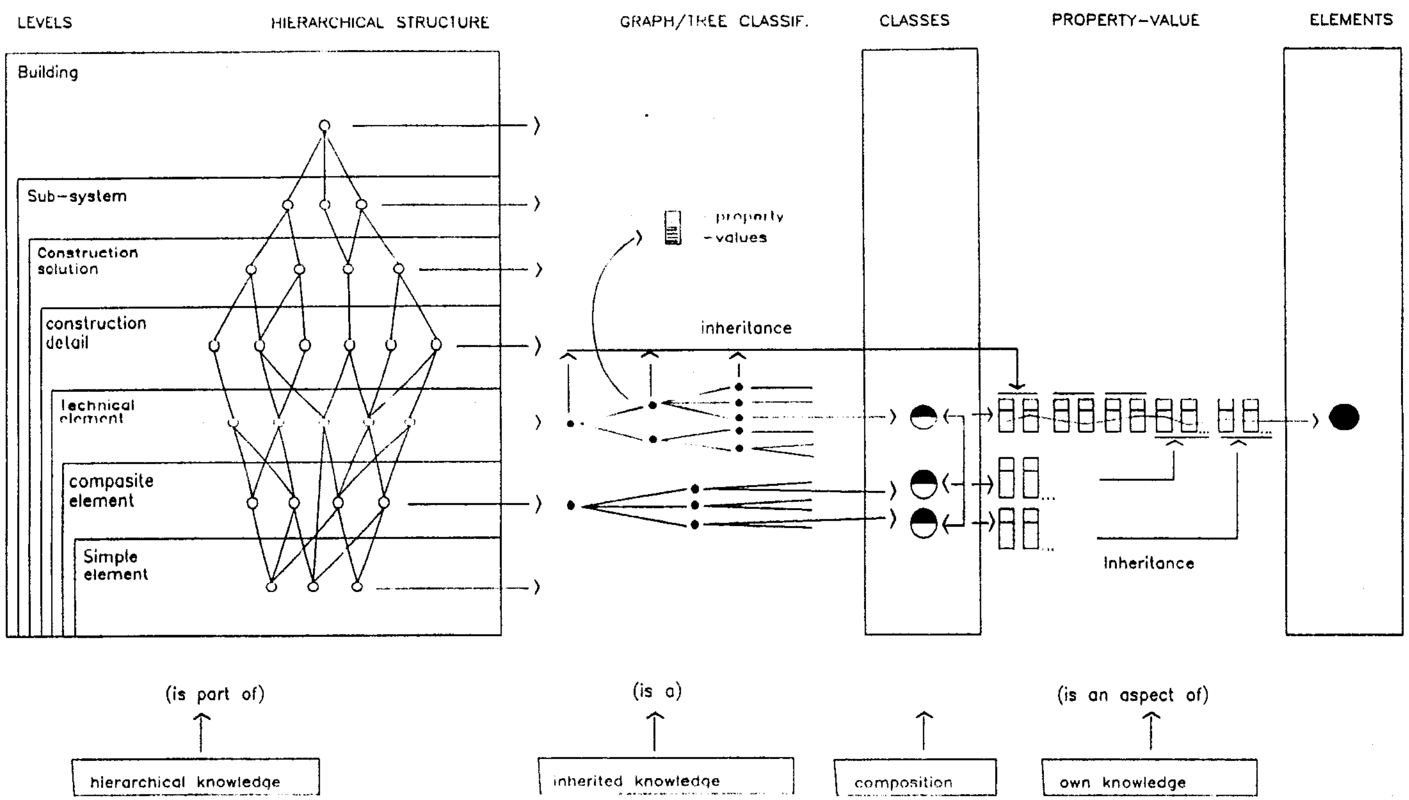

Figure 1

ceiling, party walls and ground seperators) merging data and knowledge as far as thermic, acoustic and weight requirements are concerned, taking into account as well other knowledge coming from the lower levels of the model such as incompatibility between properties, structural restrictions, property interdependency etc.

2. THE NEED FOR EXPERT SYSTEMS IN CONSTRUCTION

In the field of construction a notable development of computing methods and techniques has been observed in recent years. Both theoretical studies and practical applications appear continously. The former lack as yet a practical demonstration of their capability, whilst the later have not achieved the desired integration and remain as "isolated islands" in the general framework that represent the construction problems.

There has been little attention paid to important aspects of construction such as the control and regulation of building standards during the conceptual definition phase of a building. In other words, they still lack help tools for the user not only in the physical or structural design of the building, but also in the control of incompatibilities between materials, calculation of interdependent properties, possible limitations on values, among others.

On the other hand, it is well known that in the field of construction the number of elements and combinations of elements that can be used is enourmous. It is thus evident that a data base designed to store all these elements would be extremely large and inefficient.

However, given that the majority of information associated with any particular construction element can be considered "deductive" - i.e. that given the basic information and the rules of production or calculation it is possible to deductively calculate the rest of the values - one concludes that it is not necessary to store the vast amount of information which the number of construction elements imply.

It is for this reason that it is considered so important a parametric model for the information. The data can be represented using basic facts or elements, and the "knowledge" (that relates these data in order to obtain others) can be represented by rules. Afterwards, in run time, the rule system - the knowledge - will update the context to reflect the information deduced.

One can therefore speak of the importance of a deductive data base composed of basic elements and the knowledge associated with these elements.

There are two principal points, that should taken into account:

1) Control and regulation of standards.

2) The use of data and knowledge for deduction processes in real time.

Whilst the first point affects the whole group of levels within the SITEC model, the second point mainly affects the lower levels of the model structure.

The normative knowledge (control and regulation of standards) is translated into deductive rules for the control of conditions (General Knowledge)

The knowledge associated with the basic data is simply translated into rules of production or calculation, of control of incompatibilities among property values, structural incompatability between superior order elements, etc.

Whilst in a traditional system the representation or storage of data is given by a relational data base, in a system where there are both data and knowledge, it is necessary to use a data base capable of storing and processing knowledge. This is the case of the Object Oriented Data Bases combined with a rule system and an "inference engine", in other words, an Expert System.

It is this tool which permites the construction of a Data and Knowledge Base capable of artificially simulating that technical and scientific knowledge necessary for the development of intelligent applications within CAD applied in construction.

At the moment the value and effectiveness of Expert Systems is still open to question for the following reasons:

1) Frequently such systems have been considered as "isolated", not interconectable with other systems and, as such, their potencial and effectiveness is seriously reduced.

There did not seem to exist a clear idea as to how to manage and integrate this new technology with the existing traditional technology.

2) In general the development of Expert Systems has been realised using logical languages such as Prolog or functional languages such as Lisp. This has implied that their operation in real time has been very slow.

However, there are at the moment various Expert System platforms capable of resolving these two major objections to their use:

1) "Open" Expert Systems capable of being integrated with existing systems.

2) Development of Expert Systems in C, capable of efficiently proccesing the rules in real time and speeding up the processing of the rest of the information.

Facts of this nature have been instrumental in the planning and

development of the BECOC prototype, the basic objectives of which are:
From the point of view of Information Technology:

a) The integration of different technologies such as a the relational data base, an Expert System (sytem of rules and the object orientated data base), a graphic tool for CAD in construction, multiwindow user interface, all operating under C (Fig. 2).

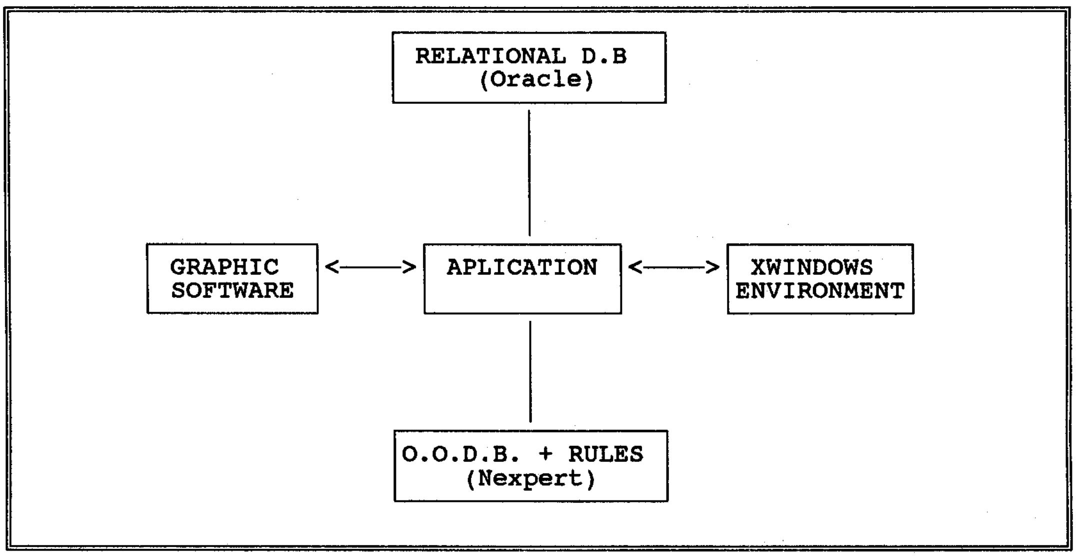

Figure 2

b) The reduction in the volume of data stored in the relational data base by means of a system of basic data combined with knowledge.

c) The development of an "intelligent" knowledge bank, capable of acting over the basic data, producing new data or controlling the consistency of the existing ones.

From the point of view of Construction:

a) The demonstration of the effectiveness of an intelligent system, such as an Expert System, based on the simulation of scientific and technical knowledge, capable of controlling and regulating the important environmental factors in the construction of a building.

b) The control in real time of any compliance failure produced during the conceptual definition phase.

3. TECHNICAL ENVIRONMENT OF THE PROTOTYPE

The application integrates Expert Systems technology with tradicional technologies such as Relacional Data Bases, 3rd and 4th generation languages and multiwindow interface.

The platform NEXPERT OBJECT was chosen for the Expert System as being that which best suited the basic requirements:

1) Open system in order to permit its intergration with other systems.

2) Potencial and efficiency in the representation and treatment of knowledge.

ORACLE was chosen as the RDB for the inicial data extraction.

The graphic module was developed using the library STARBASE. This is a small module capable of designing the objects or graphical elements needed to represent building exterior. These graphical objects are processed to give a geometric definition of the building that is later used in the assignment of construction solutions.

The user interface was developed in the XWINDOWS environment. This system allows the integration of the other modules by means of an open windows system permitting parallel tasks operation. C was chosen as the most suitable programming language.

The hardware in which the prototype was developed was a HEWLETT PACKARD Workstation 9000/340 with 8Mb of RAM, 35Mb of swap area, 300Mb of hard disk and a graphic screen of a 1280 x 1024 pixel resolution. This workstation was connected via ETHERNET to a HEWLETT PACKARD 9000/835 mainframe.

4. KNOWLEDGE BANK DESIGN

The design objectives of the knowledge bank were established to be:

1) The development of an Object Oriented Data Base in order to model the basic construction elements needed to define the exterior of a building (the representative elements within the lower levels of the SITEC hierarchy and the generic elements of the higher levels). This modelization established the base of the information representation for its posterior use under the rules system.

2) The development of a proficient Rules System, capable of being connected to the rest of the application and efficient in real time.

The necessary information was taken from the BEDEC data bank (Structured Data Bank for Construction Elements) based on the ORACLE relational database, and originally stored in the HP 9000/835 mainframe (in the BEDEC bank were stored more than 150000 construction elements).

The Object Oriented Data Base is made up of **static** information. That is, generic and closed Construction Solutions, Simple Elements and Technical Elements, all represented by means of Classes, Objectes, Properties and Metaslots.

In order to represent this Knowledge Base where used: 125 Classes with 471 Metaslots, 23 temporary Objects with 94 Metaslots and a catalogue of approximately 50 properties.

The Rule System is composed of different type rules:

1) Production Rules: formulae to calculate price, thermic coefficient, acoustic isolation, impact noise, coeficient of performance, etc.

2) Structural Rules of element composition.

3) Deductive Rules:

   a) Structural Restrictions.

   b) Interdependency between different SITEC levels.

   c) Interdenpendency between element properties.

   d) Control of thermic and acoustic standards.

Quantitavely, the Rules System breaks down as follows:

100 Rules concerning the control of standards.
50 Rules concerning incompatability and interdependency.
85 Rules of element composition.
213 Rules of calculation.

The Rule System is interconnected with the exterior by means of various subroutines in C which are called when needed. The system is capable of generating in real time **dynamic** objects that configure the group of graphical elements designed in the drawing phase. The number of elements needed to define the exterior of a building average between 200 and 2000.

As far as the efficiency of the Expert System is concerned, a large number of rules and objects causes a slow operation time. It is therefore necessary to limit the information (in terms of rules and objects) to the minimum, moving to other parts of the system all information not strictly needed in that moment. For example, using the link with the ORACLE Data Base, reduces the number of rules and the volume of information represented within the system.

5. OPERATION OF THE PTOTOTYPE

The prototype BECOC seeks to resolve the design of the building exterior assuring the compliance of the thermic, acoustic and weight requirements. The application is divided into various blocks interconnected with the kernel of the application where each block has its specific function (Fig. 3):

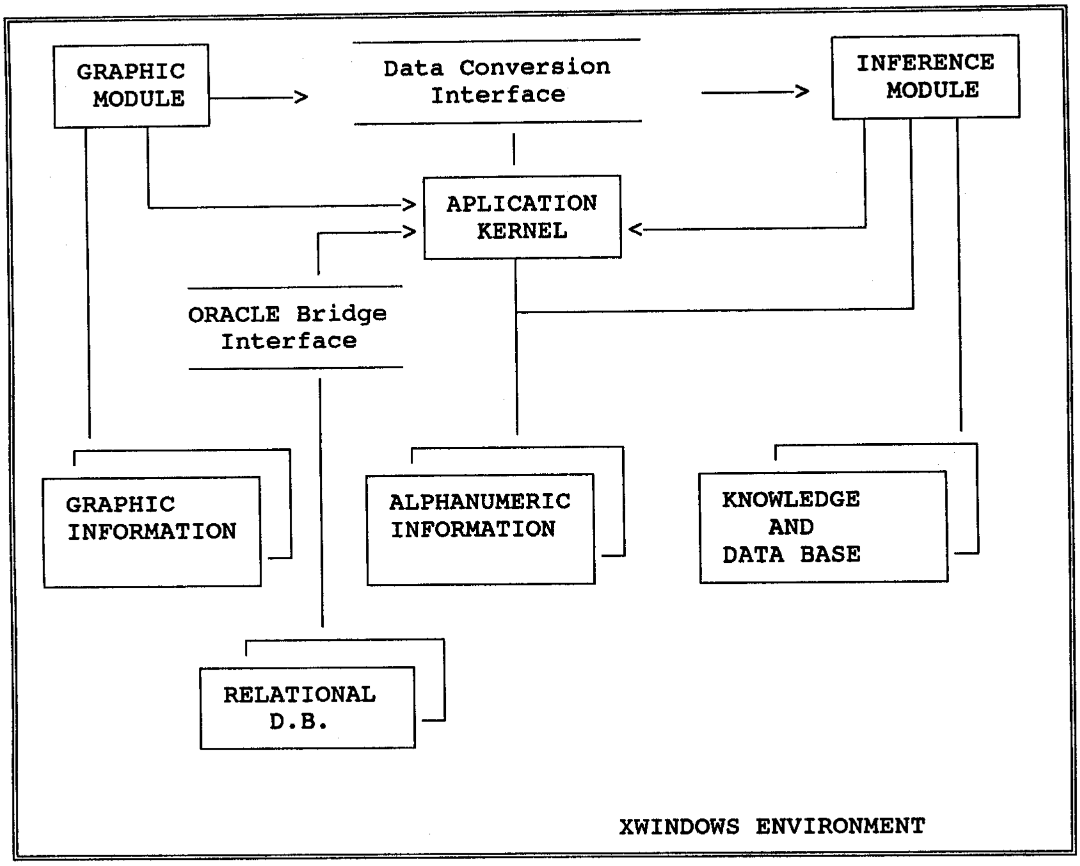

Figure 3

1) Graphic Module: A drawing tool that serves as an initial entry of the graphical data (building geometry). This data serves as the base for the process of solution assignment.

2) Inference Module: Dedicated to all the reasoning tasks that could arise during the construction process (Control of incompatability, getting values which depend on the interdependency of properties, etc.)

3) Control Module: The system of windows which controls all the events and communications produced, whether by the Graphic Module, the Inference Module or other modules (Aplication Kernel).

4) Data Conversion Interface: This process handles the "translation" of the graphic elements into Objects, Properties and values compatible with

and understood by the Expert System.

5) ORACLE Bridge Interface: This process handles the phase of translation of the necessary information for its convertion and treatment as an Object Oriented Data Base.

The principal stages in the development of the application are:

1) Drawing phase: The drawing phase of the project consists in a system of windows representing different plans such as the ground plan, the frontal elevation, 3D perspective and a "design" window where various icons allow the user to define the building exterior.

This graphic module was developed including certain restrictions, for example it is only possible to draw in perpendicular plans. These restrictions were included as the idea was not to develop a CAD tool, rather a system which was easy and quick to use to enter the graphic definition of the building exterior. Such definition is then used in the solution assignment phase which was the main objective of this work.

2) Environmental conditions phase: Determination of the enviromental or pre-existing conditions necessary for the determination of the normative knowledge (climatic zone, and heating energy source). This second phase permits the user to select the minimum conditions which satisfy the climatic and heating requirements.

3) Assignment and decision phase: The third phase consists in the assignment of a definite construction solution to each graphic element or surface unit of the building's exterior. This procedure is based on the interaction between the Expert System and the user for the precise definition of the graphical elements generated during the drawing phase.

The procedure is totally open, i.e. the user starts the definition of the elements in the order he choses and at whatever level. For example, it is possible to firstly define a Technical Element and afterwards define the Simple Elements that make up such Technical Element or vice-versa.

The system informs the user for the elements that have to be defined necessarily. For example, in the case of a double wall facade the system informs the user that it is mandatory to define the exterior and interior walls.

Should the user not define the minimum elements specified by the system, the system will consider the definition incomplete blocking the whole process,until the undefined elements are either specified or the session canceled.

The system continuously deduces and updates values from information entered by the user and/or provided by the deductions realised by the inference engine.

During operation the system controls each one of the decisions taken checking for the following:

- Posible incompatabilities that might appear between elements.
- Non-compliance of the pre-established standards.
- Structural incompatibilities in the composition of construction solutions.

For whatever change of a value produced in a property, whether by the user or the system, the inference engine automatically activates all the rules which might affect other related values, thus updating the context where necessary and checking for incongruencies should they occur. In particular, the Object Orientated Data Base is activated in order to obtain the solution to assign and the Inference module activates the Rules that operate with this information and updates the context.

Step by step the system closes the solution, using both the values entered by the user and those deduced by the system. The process is neither sequential nor driven, thus being possible to alter at any moment the value assigned to a property. The system then checks all dependent values to assure consistency and then updates the context.

Continously it is verified the fulfilment of the standards. Warnings are given to the user if non complience is observed, however, that does not necessarily mean an invalid overall solution, but the possibility of such an extreme depending on future decisions.

The relevant solution values are dynamically visualised and updated on the screen:

- Acoustic isolation, thermic transmission coefficient, weight, accumulted cost.
- At the same time the user is informed of the values imposed by the standards, namely acoustic isolation and the thermal transmission coefficient.

In the same way the overall values of the building are presented on the screen: thermal transmission coefficient of the building together with the standard value, overall cost, climatic zone according to maps 1 & 2 of the Spanish Thermic Standard (NBE CT-79).

6. CONCLUSIONS

With regards to the results obtained it is possible to draw the following conclusions:

- The treatment of knowledge has to be very closely related to the treatment given to the data, as knowledge is defined to be the generic relationship between two or more data.

- The structural relationships between elements depend on the model of data representation chosen.
- Expert Systems, understood as "intelligent actions", are not strictly sequential and could be the basis of all kinds of knowledge. Through the use of such systems it is possible to make static data banks function in a dynamic manner.
- The SITEC model supports the integration of data and knowledge acting as a dynamic design tool rather than as a theoretical representation and definition model.
- It is important to make further investigations into knowledge modelling with a view to incorporating the results in all the different aspects of CAD.

As a result of the experience carried out it is possible to conclude that the efforts have been directed toward achieving an "intelligent" system using traditional technologies such as Relational Data Bases coupled with Expert Systems and Object Oriented Data Bases.

This fact should allow to solve the "intelligent" part of knowledge representation within CAD applications in the construction field and on the other hand to make advances in the research and the improvement of the application of knowledge in real time.

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