Multi Approaches of Comfort in Architectural Design of Residential Buildings : the AMACH project.

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Presentation

The ever widening range of skills necessary for architectural design requires a specialisation of each player working together toward the same goal within a number of distributed tasks. Parallel to this dispersion of tasks, an information transfer must be established. This is rendered more important in that the domains interest several actors simultaneously and that the process is situated in the early stages of design.

Energy management for buildings is one of these tasks. It summons up at thee same time the architect and energy specialist. The very scientific nature of building energy information is very often missing in the professionnal training of architects. The complexity of the interrelation between site and climate factors on the one hand, and energetic performance evaluation on the other hand nevertheless requires the introduction of thermal evalauation, as early as the very beginning syages of design.

Building design must be driven in its entirety : a computer aided design tool cannot be restricted to a relation or optimization of just one component of the performance or the quality of the project (for example, energy savings or thermal comfort conditions), but must pay particular attention to suggest "reasonable" solutions in a given context. This induces two requirements:

-to translate decisions made in the other domains with the constructive representation peculiar to each actor of the design,

-to manage the consistency and conflicts between the information flows forwarding between the different levels of evaluation.

In this context, the multi-approaches of comfort in architectural design for dwellings (AMACH) aims at the integration of the evaluation of thermal, acoustic, visual, olfactory and spatial comfort conditions, in the early stages of a dwelling design, in a performing CAD platform: KREPIS.

This project integrates at the same time a concern for the respect of the decision process during the design, the communication between different points of view of the participating actors and optimization of constructive parameters in relation to a complex network of constraints to which the project must answer.

Two teams participate in the development of this project : one engineering school Ecole des Mines de Paris, and a private consulting enterprise specialized in computer science and building engineering, ID.BAT.

The computer tool should be available commercially in about two years.

This work is based on :

- an analysis of the design practices of the architect able to formulate models of the design process.
- A bibliographic synthesis on the knowledge and tools available nowadays for technical evaluation in these various domains.
- The elaboration of knowledge bases in each related domains materialized through simple algorithms or production rules.
- The development of multi-criteria analysis and optimization able to establish improvement strategies to the simultaneous evaluation of comfort constraints of concurrent technical domains, on a specific architectural project, and to help the choice between architectural alternatives of the project, by aggregation of the user's preferences.

-The computerized implementation in the architectural CAD program KREPIS which involved various innovative aspects:

object-programming;
performing 3D modeller;
central data base shared by all the actors;
a supervisor of constraints in the architectural design.

Models of the design process

The analysis of the architect's design practicies aims at the setting up of models of design process. To establish these models do not mean to reduce the design process to inflexible, particular and prescriptive principles: this work aims at studying the way design is and could be conducted. This includes the study of the way designers work and think, the establishment of appropriate structures within the design process, the development of new techniques in design as well as a reflexion on the nature and the importance of the use of knowledge and its application to design problems.

Furthermore, the formalisation of the design problem to be solved being an essential fondation of every informatic treatment, the establishment of a model for the architectural design process should be a priority to every development of Computer Aided Design tools.

Instead of a survey of an important number of architectural offices, we ultimately prefered a bibliographic analysis of french and foreign publications in this domain .[1], to determine the most commun evaluation practices while in the design. One of the main established result of this analysis is that an aided decision tool for architects must integrate two different approaches :

-a **didactic approach**, corresponding to the knowledge "maturation" stage, by analysis of the existing knoxledge. This is most often driven by the research of architectural references, which presents the architects with exemples of solutions, or reference buildings veri fying the different constraints : this approach is linked to an aided synthesis of the project,

-an **analytical approach**, useful in the confrontation stage of the initial shaping of the buiding to constraints resulting from general data: the context.

The computer tool for the evaluation of the different domains of comfort that we are developping must therefore not be a tool for automatic generation of projects, a process which would run counter to the design process management by architects.

This tool must, at the other hand allow:

-the evaluation of a project (clearly specified by the designer), in the multi- constrainted comfort context,
-the analysis for a project of variations obtained through the use of remedies which permit conditions respecting comfort conditions selected by the designer,
-to help choose a "satisfying" solution between different architectural projects answering to the same program.

Bibliographic synthesis of existing tools for comfort evaluation

The bibliographic synthesis of the different domains of comfort for dwellings has been materialised by a commented bibliography and a guide to comfort for dwellings[2]. This task is useful to determine the "classical" sectorial evaluation tools: from the representation of physical phenomena (thermal flow transfers, acoustical propagation...), simple algorithms to be used in the ill defined stages of design have been developped. This preliminary task is useful to prepare and adapt the knowledge structure and methods during and after the interviews.

Elaboration of the knowledge bases

We have choosen an approach of comfort for dwellings on the basis of cognaisances (in the form of production rules and simple algorithms), instead of traditionnal simulation tools. This choice was induced by our reflexion of the design process: knowledge based tools are far more adaptative than traditional simulation tools to the ill-defined, and low instrumented description available in the early stages of the design process. This work induced several tasks :

- the knowledge transfer from specialists to our research team through a set of interviews,
- the elaboration of a "frame" and object-oriented structure of language describing the physical and linguistic properties of the objects and the relationship linking them together (class, hierarchy, association, union,...),
- the elaboration of a grammar to describe methods compatible with the structure.

The knowledge transfer from specialists to the system

•The acquirement of knowledge from specialists of two technical domains, Acoustics (with Mr. MEISSER, LASA)[5], and winter thermal comfort (with Mr. BREJON, AFME), to develop analysis tools based on treatment of knowledge has been performed through a series of interviews.

These surveys were based on several interviews spaced over several weeks:
-a first series of open conversation, concerning the analysis done by the expert of test cases, step by step, using forward chaining (a diagnosis process),
-a first draft of the "expert" methods and a presentation using decision "trees" : this knowledge structuration allows to distinguish the different sources of knowledge helping to guide the system's functionning,
-a written validationof the methods with a test case,
-a computer validation of the methods with a test case,
-a computer validation (in front of a screen).
Several topics have attracted our attention through this acquisition phasis:
-the knowledge structuration of the experts is clearly influenced by the regulation methods of the technical domain involved,
-the expert's knowledge is never explicitely formalised, though it has a formidable efficiency to analyse a new situation. The human cognitive treatment is driven by extremely sophisticated control strategies to mitigate the consequences of this apparent untidiness,
-the expert re-discovers his knowledge through the knowledge structuration stage,
-diversions taken by the expert during the interviews are extremely useful to understand the problem solving process,
-a general scheme for the resolution of design must not be given rise to too early, but the clustering of knowledge facts and rules help to build efficiently the system,
-a certain delay (two or three weeks) between two interviews is important for the "sedimentation" of the formalisation of the knowledge.

•The hygrothermal summer comfort evaluation tool, already developped [3], has been validated. This work rendered invalid the choices made on thermal inertia. Upon reasonning in terms on thermal comfort, the fundamental parameter during a critical period is not the sequential inertia but the daily inertia. The punderated sum of the different levels of solarisation, inertia, and ventilation has been abandonned for priority rules established from the context of the project (type of climate, building & using).

Elaboration of the structure of the language

The first step of the knowledge synthesis consists on the definition of the general structure of the language allowing to solve design problems. A set of methods is then applied (rules or algorithms).
The definition of the structure determines the quality of the system, because this structure must be, concurently, operatively efficient and evolutionnary (easy to modify or to update). The structrure scheme developped in the AMACH project [4] is based on two fundamental objects:

a) the **elements** of structure (independant from the KREPIS system *[every expert system can support this structure]*, which are established from **logical and linguistic** formalisation of data and constraints (at the different early stages of the design) from the building project and the analysis of technical knowledge (established from the evaluation of specialists).
The structure of language is, then, composed of building elements and numerous acoustic, thermal... and symbolic entities which allow to perform the methods,

b)the **relations** (adapted to KREPIS)*[compatible with the predeterminated type of KREPIS]*. Three types of relations between symbolic objects of the structure scheme permit the description of complex links supported (figure).

These links can represent:
-1• a **simple relation** representing the link between a class X and a class Y (Ex. of class: "wall", subclasses : "outside wall" & "inside wall"...),
-2• a **hierarchic relation** representing the link between one element of a class X and N elements of a class Y (Ex.: a flat is a union of N rooms; N rooms are owned by one and only one flat),

-3• a **descriptive relation** representing a link between M elements of a class X and N elements of a class Y (Ex.: M objects cluster N associations; a window and an opaque wall are clustered in few facades).

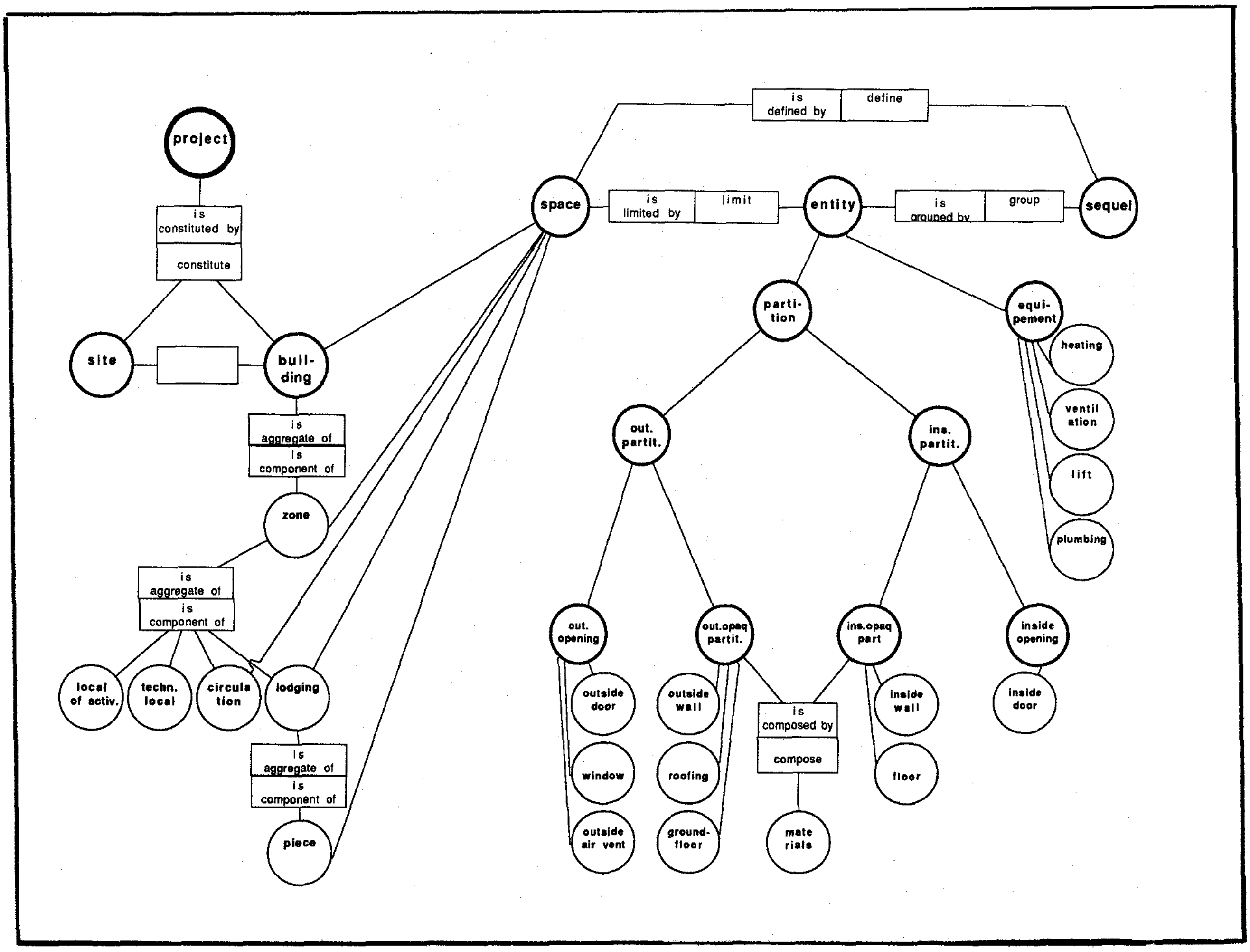
To each entity is associated:
-a set of properties or attributes (inheritaded or specific),
-a set of values for each attributes,
-a set of conditionnal procedures (sensitive to the context).

This structure is dynamic: it is possible to add attributes and values and to change values, without perturbating the functionning of the system. The structure of the language is originally linked to the logic of knowledge representation.

Logic of knowledge representation

The secund step of knowledge representation aims at developping a grammar for writing the methods, compatible with the structure scheme, either as simple algorithms (this approach was kept for summer thermal comfort evaluation), or like production rules (for winter thermal and acoustical comfort). These methods have established in a commun language (logic of order one for the last ones)

The writing of the knowledge bases using this formalism [5] [6] from knowledge sources of each evaluation technics has been done (see next figure: the constraint "aerial noises coming from outside")



Structure Scheme in AMACH

Computer writing of the knowledge bases in KREPIS

The last step of the synthesis of the knowledge is the computer writing and the validation of the knowledge bases.
KREPIS 2.1 is an environment well adaptated to the AMACH project, mainly because of the valuable structure of the language used.

KREPIS 2.1 [7] is able , through a 3D modeler, to describe geometrical and morphological properties of a project. It is able then to interprate these data and translated them into a sophisticated structure, well adaptated to the methods of evaluation: traditionnal CAD programs are often limited to the class notion. KREPIS 2.1 offers the possibility to establish many more complex links (descriptive or hierarchical [8] (figure) The information management is driven through Hypercard 2.0.

The structure of the language

The KREPIS platform has been adapted to the AMACH project to support the modification of structure induced by the knowledge bases. The structure has a static and a dynamic parts.

The **static** aspect is represented by the entities and relations which are linked directly with project data coming from the architect drawing. This part is a bridge between these data and the dynamic part. It takes into account the relations:

-UNION defines ASSOCIATION,
-UNION delimits OBJECT,
-OBJECT clusters ASSOCIATION.

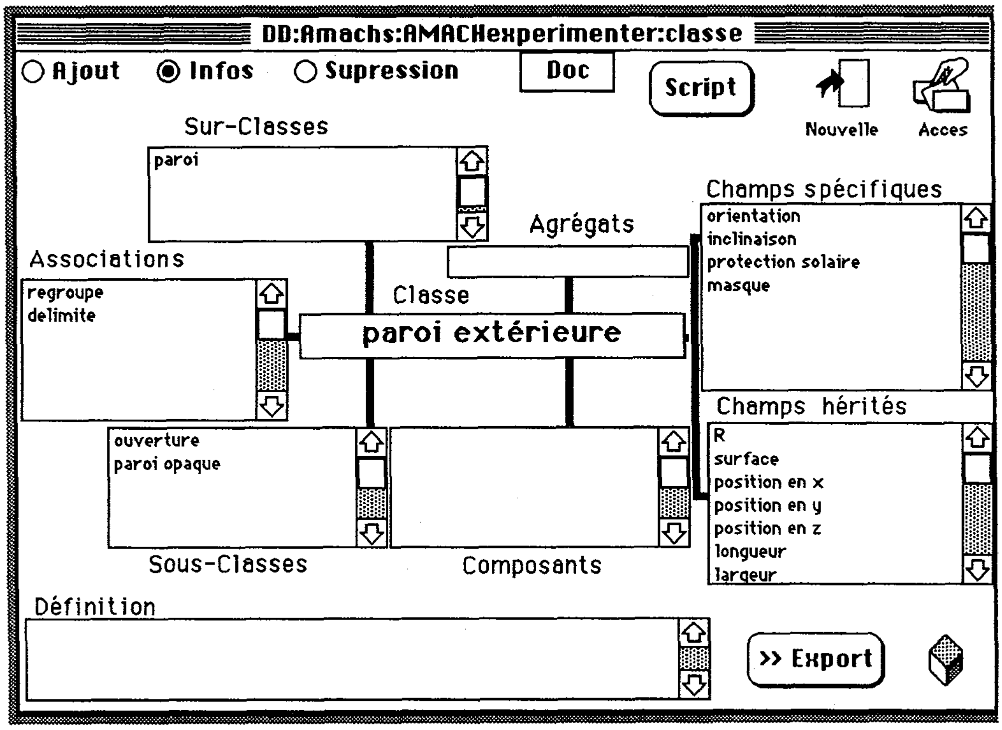
The **dynamic** aspect represents the other part of the structure were everything is possible: to add, to modify, to supress the above elements:
-classes and relations between them,
-attributs corresponding to classes,
-values corresponding to attributes.
One important task of this first stage of the project has been to build this new language structure. The valuable hypertexte language used for information management (Hypercard 2.0) is counter balanced by its relative slowness in handling it. One issue of the next stage of the project is to keep Hypercard as userfriendly interface and to transfer the data management to a SQL relationnal database (ORACLE).

The knowledge evaluation

The lack of a real inference engine in KREPIS prevents the use to:
-dependant rules,
-backward chaining,
-non monotonous logic,
-trace of the reasonning.

All these elements are necessary to build a performing interface between the user (Architect) and the system (AMACH). The requirement of an inference engine more adapted to the project has driven us to choose PROLOG II or a shell of expert systems (NEXPERT-OBJECT) to manage the knowledge evaluation.

Structure of the elements in AMACH



Multicriteria Optimization and Selection

The bibliographic synthesis on multicriteria analysis [9] proved good reason for a global evaluation of the project taking into account the different technical realms and allowing the production of variations on the project integrating accompanying and conflicting constraints on the same objects.
This work formalises the constraints in KREPIS 2.1, using Operations Research and Aided Decision technics.

Constraints are first evaluated individualy from:
-the level of valuation for each constraint,
-the flexibility on these levels.
This exhaustive evaluation is done by using knowledge bases attached to the mean and extreme values of each parameter in a given context, and varies with the level of definition of the project.

We can distinguish then, two levels in the multicriteria evaluation of the projects:
-a **multicriteria optimization** of a peculiar project by using the remedies encoded in the different constraint rules: we are directing our research, instead of dynamic linear programming technics which require a too inflexible structure to resolve the design problem, by determining, stage by stage, a set of pareto optimum set of solutions, towards **constraint programmation** in PROLOG III which combines logical programmation and a simultaneous respect of constraints,

-a **multicriteria selection** of different projects (obeying to the same program through different architectural non "commensurable" answers) within the context of the existing program. This selection, based on the agregation of user's preferences, is initiated by establishing a performance board in which appear columns which figure the elementary constraints (or their agregation for each domain) and lines appear as the different projects.

Three approaches are then possible to agregate the user's preferences, and should be available through a **toolbox** in AMACH:

-an **heuristic approach**, integrating this agregation into knowledge bases sensitive to the context of the project (type of encvironnement, building & using...),
-an **overclassification of synthesis** method, when the user is able to compare pairs of projects, based on tests on the project performance and criteria ponderation,
-an interactive approach, by **agregation-desagregation**, when the user is able to init the evaluation by a choice of prefered project(s) and a ranking of criteria. Stages of dialogue, and stages of treatment allow through trial and error an optimal solution to be reached.
A validation of these different approaches is on process.

Conclusion

The primary phase of AMACH has seen a successful appropriation by a research center (ARMINES) from a complex and performing CAD platform, KREPIS 2.0 which was developped by ID.BAT. This study has shown its value as well as its limits, instigating its restructuration in a new version so called KREPIS 2.1.

The next stage of this study is focused on an evaluation of a computer environment better adapted to the knowledge bases for writing and managing information in AMACH.
For a sub-structure of objects (vertical walls) and for two sources of knowledge, the team is testing the operationnality of a logical programmation language PROLOG II+ and its extension to constraints propagation PROLOG III, and a shell of development for expert systems (NEXPERT-OBJECT), through a rigourous analysis procedure.
The computer programmation of the complete knowledge bases for hygrothermal and acoustical comfort in the chosen environment will succeed.

The AMACH project allows architects to manipulate parameters associated with technical components of comfort in buildings, without necesseraly understanding the underlying phenomena. This tool can help:
-to develop a technical sensitivity and increase the conceptual value of the project,
-to allow the re-integration, in the early stages of design, of competencies traditionnaly introduced in the later stages:
-a pertinent knowledge about physical phenomena,
-the minimum comprehension of technical dimension of the project and of the constructive aspects of its instrumentation, through knowledge bases or algorithms,
-an optimization of the project taking into account different technical, architectural... realms.

Architects are not used to viewing their project in this way. Reintegrating main environmental principles in architectural comprehension enables to modify practices and competencies division in the design process, taking over to day's distributed tasks among different actors, while respecting their cultural differences.

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