MODEL-BASED COMPUTER AIDED MODELLING : AN APPROACH FOR BUILDING ENERGY SIMULATION IMPROVEMENT

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ABSTRACT

Many criticisms have been made about existing software for building energy analysis and simulation. In this paper, we try to show the interest of the model-based approach. The credibility of simulation results is pointed out. Main aspects of the CSTB contribution, in the framework of the GER ALMETH, are presented : the PROFORMA project about model documentation, and the MODELOTHEQUE project aiming to the design of a specific model base and its intelligent management system.

Although first tentative works have shown the interest of the approach, the proforma filling appears as a difficult task, leading to the specification of a new tool. The interest of making prototype has been raised again.

The use of more knowledge about the models may increase the capabilities of the energy analysis systems. Through the use of advanced computer tools such as orientedobject knowledge representation and heterogeneous data base management systems, the opportunity is given to design new generation modelling and simulation environment.

INTRODUCTION

For building energy analysis, usual methods are composed of a sequence of some steps:

- 1 - to identify what is the question : for instance, loads calculations, HVAC design, comfort studies, and to choose the adequate approach : adequate description of the building, specification of significant results, according to the software capabilities as well as to the problem,
- 2 - to build the model,
- 3 - to enter the data, to give the simulation plan : for instance, time steps, number of iterations,
- 4 - to run the program,
- 5 - to analyse the results : if necessary, to begin again.

The user has many difficulties ahead of him. Among them, the choice of the right point of view about the building project, (i.e. the decomposition of the building), the big amount of data to be entered, the valuation of the run parameters. Last but not least, the user has to be convinced by the results. Then he has to re-turn the whole if he wants to know "what if" he changes something.

What about the validity of the results ? It depends on many things, either from the user or from the program. Different levels of error are frequent: input of data, etc... Does the description of the project correspond to the thermal point of view for the problem ?
Does the algorithm give the correct results in this case ? Is this problem solvable with the method embedded in the code ? ... In fact, implicit engineering and modelling expertise are encapsulated inside the procedures and the main program. The assumptions that the developers have built in may not be appropriate to the user's specific problem. Moreover, the system may deliver some results, but it may in fact have solved another problem.

How to improve it ? What may be the specification of an advanced environment

for modelling and simulation ? The identification of each stage of the modelling task gives a list of critical points under the validation respect.
[BALCI 1987] points out the importance of separating the model from its expressions and its experimentation. He shows that the model building stage is a key point.

In building energy analysis, modelling approaches are usually component-based.
Let us see how a model is being built. The modeller considers some sub-parts of the problem. For each part, he writes down some behaviour description, either by using equation, or any other formalism. This decomposition is problem driven; it may be based upon the real objects or upon the thermal phenomenas. It implies that the decomposition of the project into accurate pieces is an important part of the modelling task. In fact, sub-parts are often the same : a boiler or a pipe for example. So, it should be easier to take the model of each sub-part from a library. The problem is : the decomposition may vary, and give different boundaries of each sub-part. So this library must be able to propose different kinds of elementary models, with specific assumptions, and to help the user in choosing them.

Most usual models are based on a mixing of experimental fit and phenomenological rules, adapted to some problem by derivative or heuristic principles: they may be called "adapted models" [LARET 1988]. Note that one object of the real world may be represented by a lot of models, at different levels of knowledge, and/or from different considerations (the "aspects" of [ZEIGLER, DE WAEL 1984]).
In this paper, we emphasize the next point, i.e. the selection of an accurate model for each elementary piece, and the coupling of this model with the others in order to build the model of the whole system.
Validity assessment is built by the careful way of doing each step: particularly, the connection between models, using the detailed nomenclatura and their assumptions.

Two points are then enlightened :
- first one , the necessity to associate with each elementary model a precise documentation about its assumptions and its validity rules (Proforma project) ;
- second one, the need for advanced model base management system, giving selection and assembling functions (Modelotheque project).

THE DOCUMENTATION OF THE MODEL: THE PROFORMA

Most of these functions need knowledge about models : the proforma, documents filled by the authors and given with model, are basically important for the modelotheque. Inspired by the "DATAPROCESSOR PROFORMA" proposed in 1984 by the ABACUS and LPB Groups to the I.E.A. Working Groups, a first draft of the Model Proforma was released by the CSTB [SORNAY 1985], in the GER ALMETH after a consensus between the research teams involved in the field (INSA, CSTB, ENSMP, CNRS, FNB, AFME). This structure is being used for describing some well-known models, to test its expressive ability.
The goals of this project are:
- a documentation about existing models, a kind of handbook of algorithms.
- help to users for modelling. This will call validity clauses and rules about model use. As far as possible, automatic modelling will be available.
- ability to give default values, and validated data.

A proforma contains several chapters,

I : a short page, giving essential information for identification of the model (physical object, thermical problem, method,...)

II : a formal description, by schemas, and specifications on input, output and parameters ;

III : validity clauses and rules of use or practice ; in this chapter there will also be consistence and compatibility rules for solving stage ;

IV, V: data about validation tests, authors and scientific references.

Together, one model and its associated proforma are an entity of the modelotheque. Access and manipulation primitives are given by the database management.

The use of object oriented paradigm will facilitate the building of the model base structure. The decomposition of an object is different according to the kind of problem: for instance, you can see a boiler either as a black box, with very simple representation (heat power vs consumption?), or as a composition of a burner, an exchanger, a chimney etc..., or again by some thermal phenomena: convective, radiative, conductive and mass flows. So, models may be classified not only by aspects, but also by their level (detailed vs simplified) and their assumptions, i.e. the way they are derivated from reference model - or sometimes, built from experimentation. This conceptual structuration is a part of domain knowledge. [SORNAY 1985], [SORNAY, DUBOIS 1986].

PROFORMA TESTS

Some models are already documented through this formalism, ..but the fitting task seems to be a very awkward and difficult one. So it is necessary to give a help procedure with proforma questionnaire. It includes explanations about the data structure of the model base, so as to give the filler some a priori description of variables, parameters, etc, with thermal domain thesaurus and menu-driven help.

THE MODELOTHEQUE PROJECT

The proforma base has two goals : to give access by keywords to the proforma entities, to give an aid to use the model in modelling problems: this task concerns the step 2.
First functional analysis of Modelotheque requires different basic functions [DUBOIS1986]:

- on line model consultation, for user documentation;
- selection of models : selection of a list of a priori usable models and interactive choice of the "best model" (the simplest one that give the expected precision on requested results ?);
- instantiation of a model: this function searchs for the actual arguments, parameters values, etc...and when needed, asks a data base. A part of the task is the choice of input and output from non-oriented plugging variables.
- validation : at each elementary step, this function ascertains that the building of the model obeys all assumptions of the general framework. ;
- assembling : if the elementary model is accepted, then it has to be connected by plugs with the actual in-building model.
- tracing function, gathering all information about practical uses of the model
- facilities as user's library and definition of "macro-models"...

A PRELIMINARY DRAFT

After this first stage analysis, it seemed necessary to test main ideas and to make some drafts. Objectives were to give a realistic idea of what a proforma base management could be, and to enlight what are the important points of proforma management. This draft was written in PROLOG, to benefit of the easiness of this declarative language, and its internal inference system. [ISI 1987]. It has allowed us interesting experiences and raised some questions.

All our proforma-filling experiments raise again the need for a thesaurus of the domain that everybody in the field would agree on. Another interesting fact is the possible role of such a draft in a knowledge-acquiring methodology. While the expert is using the software, in fact, he gives some fundamental comments about the way the model has to be built. The system acts like a mirror. Despite the weaknesses of the draft interfaces, we may obtain some precious information, invaluable help to grasp the definition of the concept of "demarche" (i.e. modelling processes) that is central to the modelling knowledge.

CONCLUSION

Model-based computer aided modelling offers some exciting promises. This approach concerns many engineering domains and some researches are going on this way. It is clear that more knowledge about the models may increase the capabilities of the energy analysis systems. Through the use of advanced computer tools such as oriented-object knowledge representation and heterogeneous data base management systems, the opportunity is given to design new generation modelling and simulation environment.

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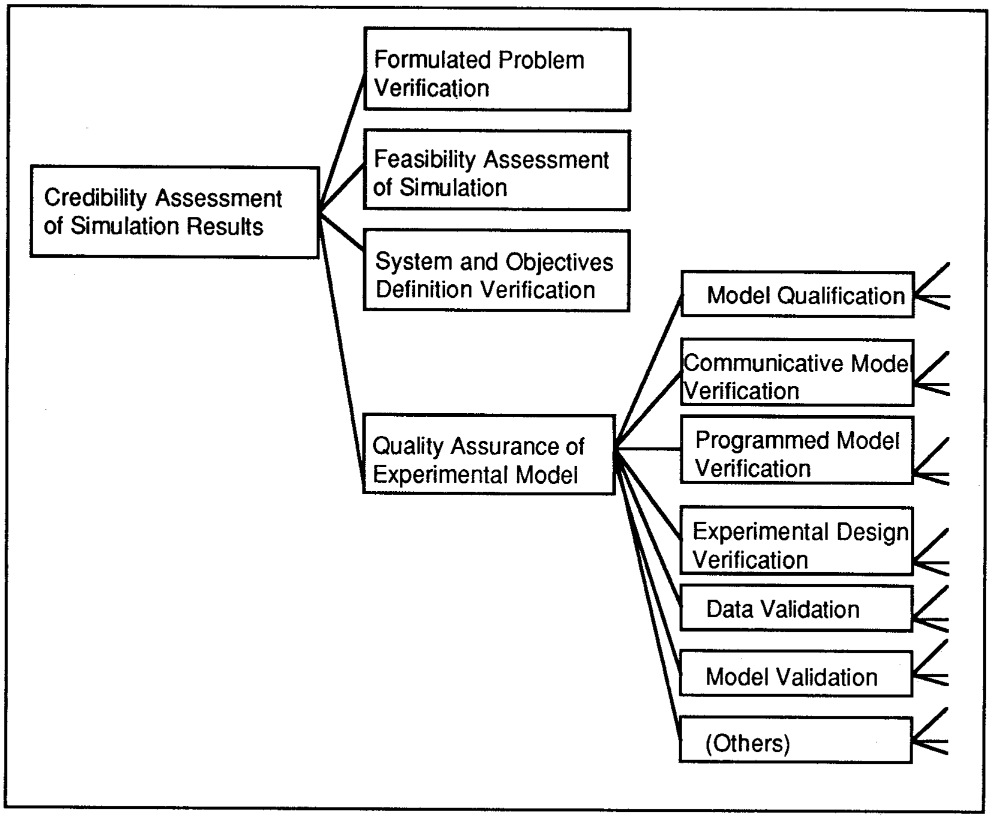

Figure 1 : The credibility assessment of simulation results - from O. BALCI.

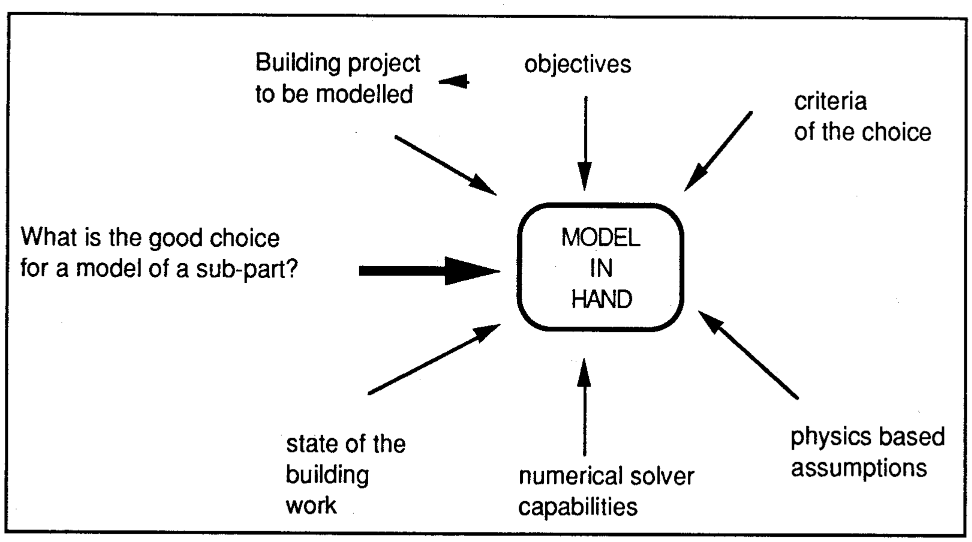

Figure 2.

DESCRIPTION OF PROFORMA -- (GER ALMETH proposals - may 1986)
<MODEL NAME> Date

CHAP 1: (a short page)
GENERIC NAME, i.e composed name, (physical object, thermal problem, major assumptions, method, and indication about (intrinsic, coupled, interfacing)
ABSTRACT (10 lines max)
THEORETICAL APPROACH (simplified, detailed,..)
VALIDATION MODE (analytical, experimental, comparison-based,..)
MODEL TYPE that can be algorithm, numerical, equations
GENERAL INFORMATION: authors'name, references of the proforma filling (date,translater's name)

CHAP 2: formal description
NOMENCLATURE: each name will be follow by a description, units, type (real, integer, character, discrete,..), values domain, default value, and if exists, other constraints.
FUNCTIONAL SCHEME describing the model's core: how the problem is managed, which treatments upon the data, etc...
BLOCK SCHEME: I/O schematic, distinguishing parameters, input/output, variables (of equations), and external methods used. There we see the plugs of the model box.
FORMULATIONS than can be equations, algorithms, or logical rules.

CHAP 3: validity clauses
DETAILED ASSUMPTIONS and VALIDITY BOUNDARIES (on I/O or parameters values, time step, etc..)
APPLICATIONS LIST using the common user's description language
EQUIVALENT PROFORMAS
UPSTREAM MODELS acting as mechanisms for this model
COMPATIBILITY RULES for the solving stage
PROBLEMS OR BUGS

CHAP 4: VALIDATION TESTS Description or references of validation tests and comments

CHAP 5: REFERENCES Explanations and references of the theory.

Figure 3. Description of Proforma.

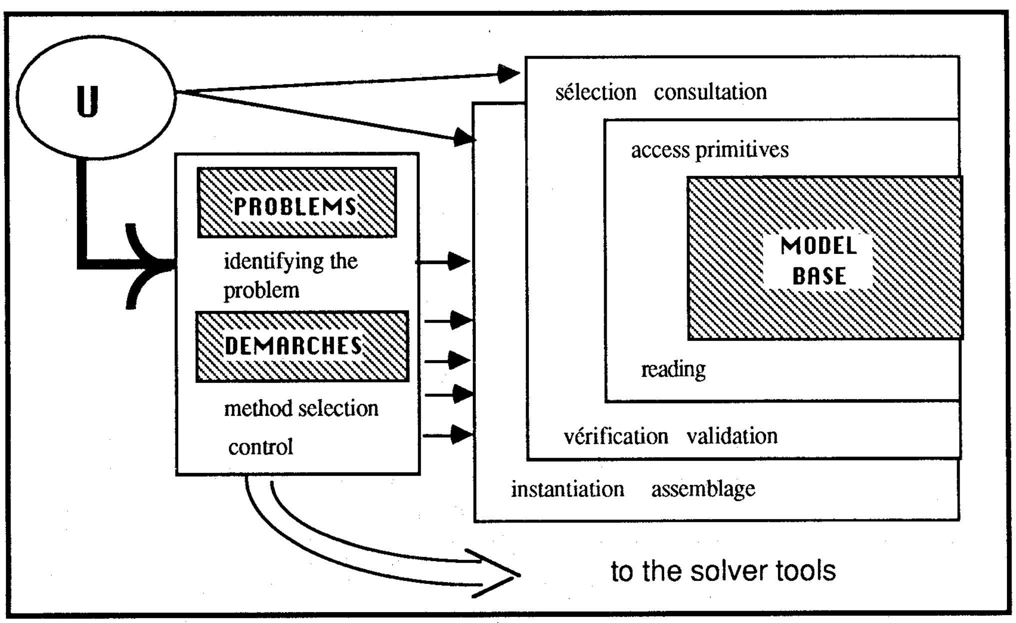

Figure 4 : The general framework of the modelling environment.