BUILDING AND HVAC SIMULATION : THE NEED OF WELL-SUITED MODELS

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ABSTRACT
Recently, the more accurate comparisons between the existing building behaviour and the simulations have shown that a more realistic model of the whole system has to be considered. In fact, the coupling effects and feedback loops between building, HVAC equipments and the control, are essential and can only be taken into account by a large scale simulation. This observation emerged more and more during the last three years. But, unfortunatly the direct coupling of the existing models in the same simulation software was not often possible. Moreover, when the coupling was possible, the resulting coupled set of equations could not be numerically processed, due to numerical difficulties.
As a matter of fact, during the modelling of each component of the whole system, the further coupling has to be considered and adequate models for this purpose must be designed.
This paper analyses this aspect of the problem and proposes some solutions and examples for the component model formulation.

I GENERALITY ON MODELS, MODELLING AND SIMULATION

Models can be defined as abstract representations of some part of the real world which can be processed in order to predict the future behaviour.

The simulation is the use of the model in a well-defined situation (following ZEIGLER : the experimental frame) in order to give the expected (depending on the user goal) behavioural prediction of some part of the real world.

Modelling is the action of building models. This task lies on the existing fundamental knowledge (models, principles,...) and the empirical knowledge (experimental observation, validation, credibility).

The inference property appears clearly : models are able to give more information than required for building them. In other words (following NASLIN), models are able to produce a more rich behaviour than required by the observation used for building them.

Modelling is the hearth of intelligent behaviour : "goal seeking" and "goal oriented" systems. In fact, presently, it is the most reachable and better formulized part of Intelligence. The use of "better" models (fast enough, accurate enough or well-suited to the goal) allows deeper predictions and a more powerful goal oriented strategy. The principle of this process is schematized on figure 1.

The human beeing superiority is due to its ability to learn the human knowledge by models, to process it and to produce new conceptual knowledge which can be recorded and communicated easily [4].

Without entering in more details, an essential aspect has clearly emerged : "adequate", "better", "depending on the goal"... models. Obviously, the model is strongly depending on its use, thus on the goal itself. Modelling has thus to be directed by the goal.

Presently, the further improvements of buildings and HVAC systems imply a coupled analysis. The existing buildings or HVAC models are not flexible enough for this purpose [1], [2], [3].

2 MODELLING BY COMPOSITION

A first and obvious way to make modelling more efficient is to re-use basic existing pieces or component models : modularity of the modelling itself. This means that modelling have first to cut the object in some pieces, after selecting the appropriate component model in a library and finally to link the basic models to produce the desired global model.

Presently, some coordinated efforts are made or are in progress in order to collect the existing model knowledge [5], [6], and to process them by a knowledge base manager [6]. The conceptual approach and the development of adequate methodology to collect and process knowledge [6] and to link the user (top-down approach) with the research product (bottom-up approach) [7] will be the essential future tasks.

But, it is obvious that some basic models are more flexible or more re-usable than others. During the modelling process, and the further use of the model, several steps are to be discriminated as shown on figure 2 for a building and HVAC example. The library of pieces or component models can be produced for any level, but the flexibility of model use or adaptability decreases from the physical to the computer code layer. On the contrary, the numerical usability for a specific application increases.

3 LEVEL IN MODELLING

Figure 3 schematizes different possible level of models following two directions : level of detail and genericity versus usability on the horizontal direction and level of computability versus flexibility on the vertical axis.

Existing models are almost always proposed as follows :

- At the detailed level either by equations (Partial Differential Equations) either by very heavy computation codes (multiplicity of inputs) which cannot be used as sub-systems of a more complex system.
- At the empirical level by obvious relations where the parameters are to be identified.

In this situation, due to the very different modelling levels of the existing models, it is practically impossible to produce a well balanced coupled system.

An intermediate level must be specified were the genericity of the model allows the easiness of well balanced assembling (adaptable model) and a reasonable effort for computation of large scale systems.

In figure 3 scheme, these models are called adapted models and are considered at the mathematical layer, where a strong link with the physical meaning is maintained. Thus the component model genericity and flexibility is preserved, and the computability remains possible by the existing techniques.

For instance, the energy conservation for heat transfer can be expressed by a physical state space equations where temperatures are potential from which heat flow derives. The level of detail depends on the model order. Starting from detailed or reference models, simple rules of simplified physics allow the order reduction maintaining naturally a physical link between the different order models.

This process has been described and applied for several components : building multizone [8], domestic hot water boiler [9] [10], hot water network [12]. Each of these models can be easily computed at different levels of detailed and can be linked without any problem [11].

4 PARAMETERS AND STANDARD DATA

These "well suited" or "adapted" ("adaptable") models can be simplified at a very reduced level. At this level, the model parameters can be directly identified on the standard test manufacturer data. It is also possible to establish directly the equivalence with the standard parameters issued from the standard tests. This property is essential for the future generation of simulation tools. In fact, for most components the standard or manufacturer data are the only one accessible. But the computability of the corresponding models in assembling cannot be adapted at a given level of detail. Very often, the parameters have no meaning (what is the physical meaning of the coefficient of a polynominal fit ?) and the extrapolations are prohibited.

On the contrary, the simplified physical rules allow to extrapolate a more detailed and well-suited model as soon as the modelled object is defined [8], [11], as shown in figure 4.

5 CONCLUSIONS

The present and future analyses imply the coupled simulation of large scale systems, involving building and HVAC equipments.

Existing models of building or HVAC equipments are either :

- too simple to be used in accurate enough large scale simulations,
- too detailed and heavy to be used easily in reasonable coupling ; moreover, very often, the required parameters cannot be supplied.

Thus, "well-suited" models are to be designed in this aim. A process where models remain at the mathematical equation level is the most appropriate for easy link. A reasonable level of computability has to be maintained. The state space equations appears at the best compromize.

Finally, in order to ensure the genericity, a strong physical meaning must be supplied. The definition of a physical state space and the corresponding rules of physical reduction offers all the required specifications on the parameters and model level adaptability. Several practical examples have already been proposed [8], [9], [10], [11], and implemented [12].

The approach based on simplified physics rules maintains a strong link between the users (performance evaluation tools and simulation) and the developments issued from the research community (model and modelling).

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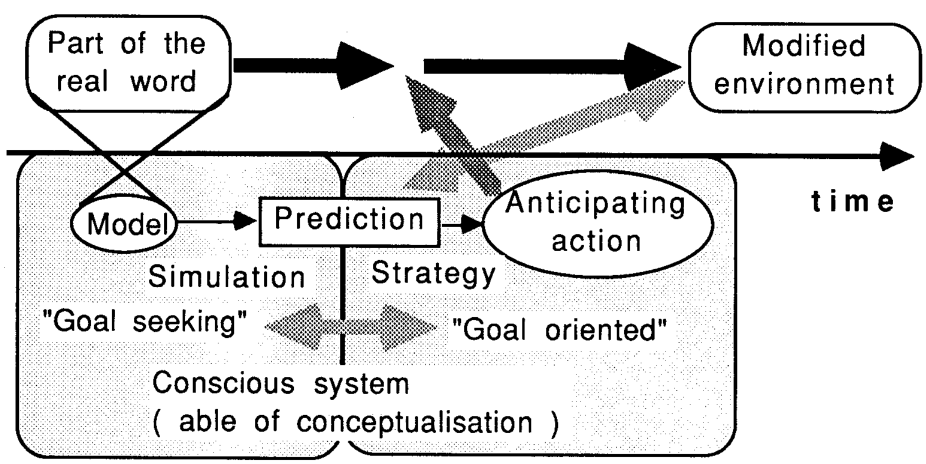

Figure 1. - Intelligent system behaviour and interaction with the real world

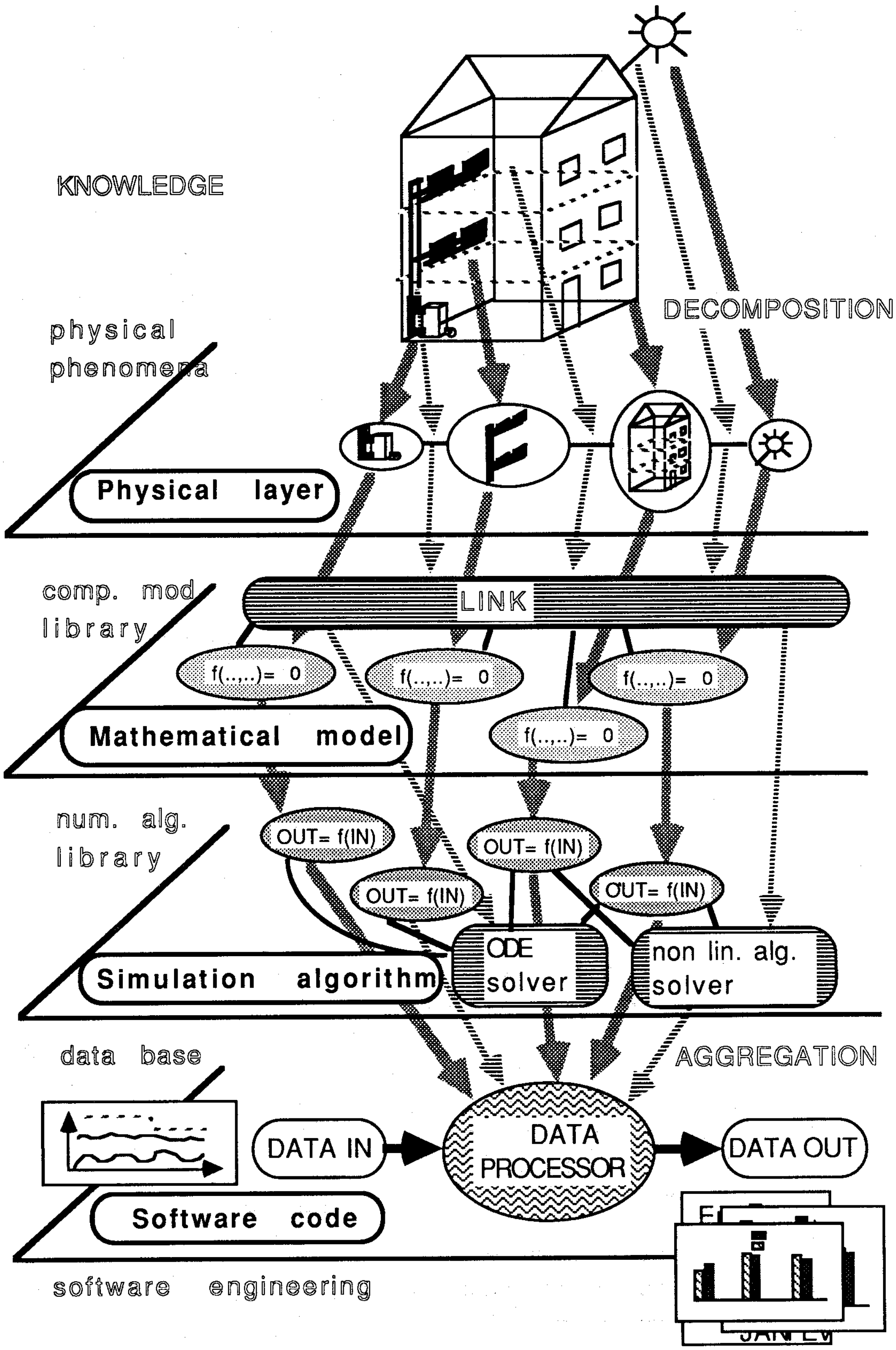

Figure 2. - The decomposition-aggregation during the different steps from building

qnd HVAC system to the simulation results.

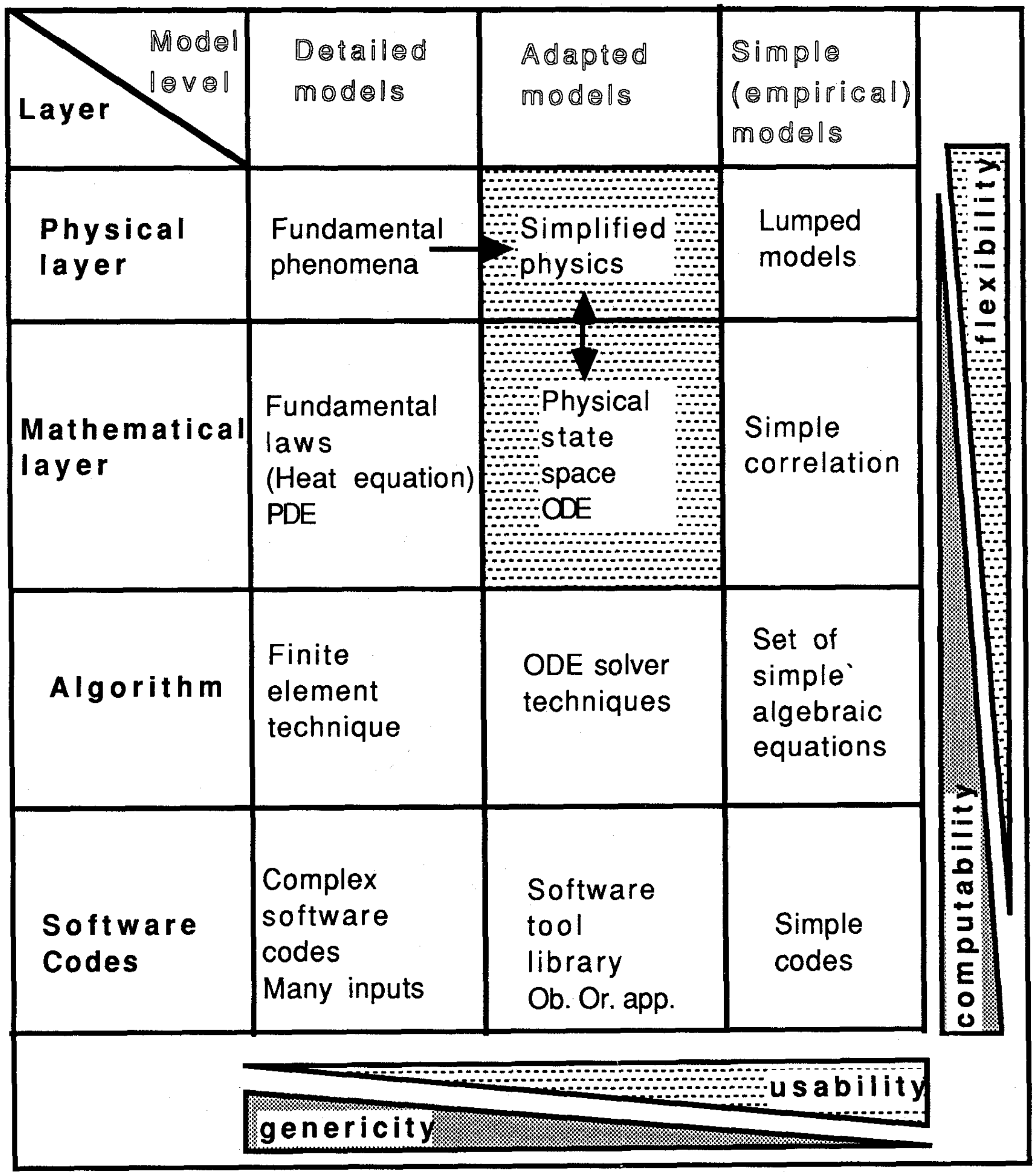

Figure 3. - The different model levels for the different layer from concepts to software tools.

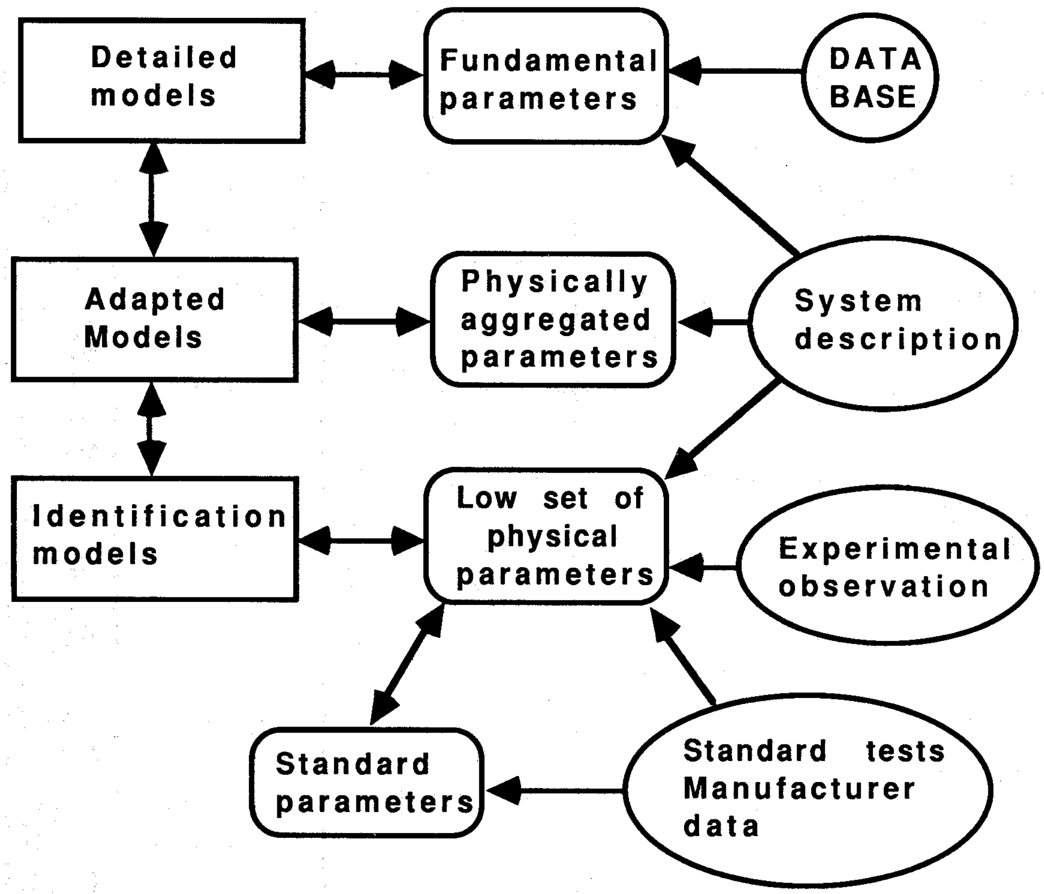

Figure 4. - The link between standard tests and manufacturer data with the basic description and data by the physical rules and the different model levels.