THE ALMETH PROJECT ZOOM CODE : RESULTS AND PERSPECTIVES

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ABSTRACT

The TEF (Transfer Evolution Formalism) and the ZOOM software (Zone Organized Optimal Modelling) have been developped in order to give a flexible framework for physics oriented modelling. Their construction is based on a clear statement of the necessary partition ning/interfacing process, which leads to the definitions of the two classes of simulation objects : cells (elementary physical systems) and transfers (interfacing cells). This structure is the basis for system nesting and coupling analysis implementation. The desired flexibility is obtained through user oriented languages structured in layers following the ALMETH world-layer grid. Further adaptability will be brought up by present new tool development : time nesting, asymptotic analysis, and steady state computation.

TEF and ZOOM evolution in the forthcoming years shall be concerned with the application of ZOOM to experiment analysis, the implementation of parallel processing taking advantage of the tree structure of TEF, and the opening of new physics modelling fields.

INTRODUCTION

At the beginning of last decade, new concepts upon simulation had appeared, embracing new needs in demand among scientists and designers (such as modularity, flexibility of tools, multimodel handling, etc.).

Simultaneously, the computer field development, languages and AI software innovations allow better integration between specific field-of-application concepts and software tools.

These two aspects should give the possibilities of a break through to a new generation of modeling tools that could fill the present gap between designer's needs and available building performance system analysis softwares. This leads to two classes of requirements :

• A large variety of physical model development to contribute to credible simulation of the building behaviour :

- passive type models, like natural convection, ventilation, heat and mass transfer between walls and inside air, building and soil, etc. ; the problem is to integrate recent and on-going physics research solutions in a modular and versatile form ;

- HVACS type models ; the purpose is to get component form as well as flexible customized assembling tools in order to build realistic HVACS strongly coupled loops in relation with their environment through "distributed" interactions.

• The development of systemic methods to cope with large and complex multimodel simulation :

- on one hand, the complexity of connecting heterogeneous models raises the need for highly flexible and robust solvers ;

- on the other hand, the tremendous amount of simulation datas produced can be wasted if no tools exist to produce valuable synthetic informations at different levels of approach of the system (ZOOMing on results).

The goal of the ZOOM collaboration is to give coherent solutions for these two classes of requirements ; the two labs of the collaboration (LESETH - Université Paul Sabatier, Toulouse - and RAMSES - CNRS, Orsay) are part of a national collaborative project ALMETH, sponsored by the French Agency for Energy Management (AFME).

THE ZOOM CODE PRESENT FUNCTIONNALITIES

Partitionning

The basic concept of ZOOM is the idea that, given a complex system (building, part of building, technical device, complex physical process, etc.), the search for the intelligence of the system goes through a double movement :

(i) decomposition or partitionning ("divide and conquer")
(ii) re-assembling (analyse, solve, synthesis)

The initial system is decomposed by the user in subparts, called families, the result being a question :
"What inter-influences of parts explain the undecomposed system behavior ?"

Each family is in turn partitionned until some part is recognized as a standard family, or as an elementary object, both refering to a knowledge based library.

The user interaction with the software tool is developped in the ALMETH project by the CSTB (Centre Scientifique et Technique du Bâtiment); the ZOOM collaboration is concerned mainly with the algorithmic aspects of the systemic, mathematic and numerical implications of the resulting tree structure of this top-down approach.

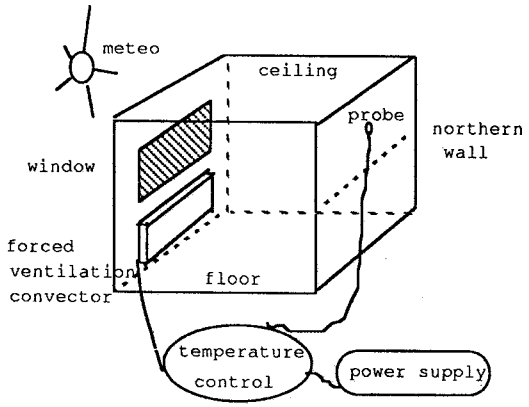

Fig. 1

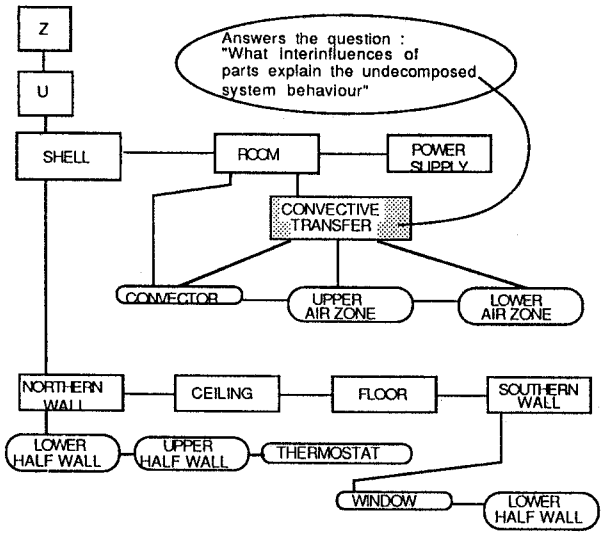

Fig. 2

Coupling and Interfacing

Supposing available the physical knowledge on elementary processes, the bottom-up problem raises a fundamental question of finding generic methods to restore the dynamic coupling between objects, as well as producing agregated coupling information for the upper levels from the characteristics of elementary couplings.

The TEF (Transfer Evolution Formalism) has been specifically developped to create interfaces between physical elementary processes : each classical elementary model has to be augmented by some mathematical operator giving the model sensibility to its environment.

The inter-influence between macro-objects (families) are in turn given by macro interface operators built from more elementary interface operators.

These two basic functionnalities of ZOOM fulfill the modularity requirement as well as flexibility, in the sense that the resulting system response does not depend on the user partitionning choices.

The cost of these functionnalities is a considerable algorithmic complexity of the ZOOM software environment. However, a good transparency of the operations induced by the partitionning/coupling process is needed. Development of generic tools allowing system handling, visualization, and management will answer this demand. The success of this double challenge is made possible by two recent developments of the computer field :
- massive parallel processing,
- generic software tools.

SPECIFICITY OF THE ZOOM COLLABORATION POINT OF VIEW

It has been pointed out that an integrated software tool should allow a user oriented approach (top-down) toward the studied system (Augenbroe and Laret, 1988). We believe that the tree structure partitionning of ZOOM insures a deep coherence between the user's top-down approach and the bottom-up software developer movement, as it follows in both cases a "divide and ask" process.

Nevertheless, our views differ greatly from a common opinion on integrated tool stated in Augenbroe and Laret (1988)* : we strongly believe that the tool has to give pertinent physics (or systemic) characteristics of the system to the user in an interactive driven manner. Coherently, the physical layer of the modelling process with ZOOM is the central point of development : moreover, if we take as a future break through the raise of qualitative forms of results, allowing the thermal behaviour of building to join a broader multicriterion (as for expert systems) analysis of a city planning project, we believe that the physical analysis of the system is inevitably on the way.

THE TEF BASIS

Two Simulation Object Classes

Within TEF framework, two kinds of simulation objects appear :

(i) The cells, representing the system components (spatial domains, subsystems, etc.). The timewise evolution of each cell (α) state variables is supposed to depend only on state variables η_α and on a vector coupling quantity φ connected to cell (α) :

$$\partial_t \eta_\alpha = G(\eta_\alpha, \varphi)$$

(ii) The transfers, representing physical interfaces (or coupling processes) : these transfers are defined by matching relations that express the interface transfer variables φ as a function of state variables η of cells connected to that interface and variables of transfers φ' connected to these same cells :

$$\varphi = f(\eta, \varphi')$$

* "Within a given context (...) the Building Performance Evaluation Tool has to behave ideally completely autonomous. By this we mean that the design-user must be able to "drive" the tool essentially without being aware of the underlying simulation and modelling process".

The software implementation of these two kinds of objects is achieved in generic processors ; one can make a handy description of processors by means of usual block diagram.

Cell Processor Block Diagram

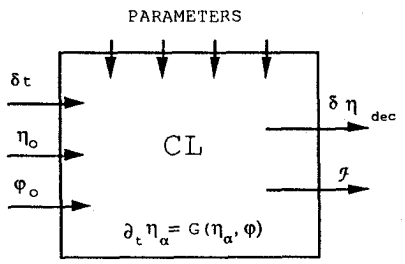

Fig. 3

Inputs :

- state η_0 and transfer φ_0 variables at the beginning of the time step δt.

Outputs :

- $\delta\eta_{dec}$: evolution the cell would follow during the time step if it were decoupled from its environment
- $\mathcal{F}$: matrix representing transfer influence upon cell evolution

Outputs derived from TEF model can be written :

$$\delta\eta = \delta\eta_{dec} + \mathcal{F}\,\delta\varphi$$

At this stage of modelization, the TEF rephrasing permits the set up of coupling analysis. Indeed, the block diagram expresses for each cell a crucial splitting between decoupled and environment driven evolution : this is the keystone for coupling analysis.

Transfer Processor Block Diagram

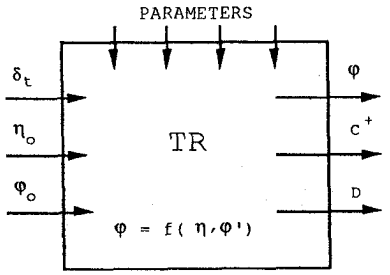

Fig. 4

Inputs :

- initial state of connected cells and transfers

Outputs :

- transfer value φ ; when φ is both an input and an output value, one needs to compute it by using a relaxation process
- C+ matrix describes cell influence upon this transfer ($\delta f/\delta\eta$)
- D matrix describes other connected transfer direct influence ($\delta f/\delta\varphi$)

Eliminating state variables, TEF leads to the key equation :

$$(1 + D + \delta t\,\mathcal{A})\,\delta\varphi = \delta\varphi_{ins}$$

where $\mathcal{A} = C^+\,\mathcal{F}$.

We call $\mathcal{C}$ the coupling matrix: $1 + D + \delta t\,\mathcal{A}$.

This shows how transfer evolutions dj are moved away from their insensible behavior dj_{ins} (the one that φ would follow if cells were on their own decoupled evolution).

It can be noted that if the preceeding formulas give the time wise form of the models, linear system can be simulated as well in their Laplace transform, exhibiting very similar coupling matrices. Another aspect of the TEF is its recursivity, which allows a symbolic treatment of problems.

THE KERNEL ORGANIZATION AND THE NESTED SOLVING PROCESS

Generally $\mathcal{C}$, $\mathcal{A}$ and D matrix dimensions are quite large. However, they are sparse matrices : they have vanishing coupling element for every pair of transfer variables for which there exist no cell connected to both transfers. Operators having this property are called nested operators. It can be shown* that this tree structure issued from the user partitionning is pertinent to construct appropriate algebraic solvers. This fact gives the actual possibility of treating large systems and of performing coupling analysis (Bonin and others, 1987, 1989).

Thus, the family concept has an equivalence in the solver elementary operations, and the algebraic operators are closely related to the interfaces between families, and finally the solving process is far from a black box classical "integrated tool" as it inherits the user expertise. These very basic facilities of ZOOM will be enhanced through the development of a systemic theory called HED (Hierarchized Eco-Dynamics).

ZOOM PRESENT STATUS AND DEVELOPMENT

ZOOM present structure was developped in order to make usable the TEF/HED concepts while applying them to research physical problems. Flexibility and practicability led to the implementation of coherent languages structured in layers following the ALMETH world-layer grid (Dubois, 1990 ; ALMETH, 1991). Presently, six languages exist or are under development, spread over three worlds :

Technical	none		
Physical	ZDL	PDL	
Mathematical		HMB	
Numerical	none		
Computer science		ZBM	ZTM
		ALLIS	

* unpublished TEF/HED manual for a ZOOM workshop to stand in 91

Each of these languages corresponds to a given process of the modelization :

- ALLIS (ADA Like Language) : programming
- ZBM (ZOOM Bank Manager) : data handling
- HMB (Hessian Matrix Builder) : symbolic mathematics
- PDL (Processor Design Language) : interfacing
- ZDL (ZOOM Design Language) : partitionning/ assembling.

The first two languages, together with the ZTM (ZOOM Tree Manager : structure manipulation) are intended for software development, whereas the three others are user-oriented.

More precisely, PDL specifies the interface part of models ; it deals with the structure of the coupling operators ($\mathcal{F}$ for cells ; C+ and D for transfers) that have to be computed by the processors. ZDL specifies the partitionning and assembling (or connnecting) used for the simulation : it is the actual input of the simulation.

Except for ZDL (which exists since 1988) and ZTM, ZOOM development proceeds by piling up language layers, each process definition yielding the specifications for lower level languages. As upper layers become more and more precisely defined, low layer language implementation gets more complete. At the present time, ALLIS and ZBM layers are nearly saturated ; HMB and PDL are developping.

EXAMPLES

Modeling of Natural Convection Boundary Layer near a Hot Wall of a Dwelling Room

Natural convection temperature and velocity fields in cubical enclosures have been studied experimentally by the french collaboration "ARC Convection Naturelle dans l'Habitat" (1986).

For a certain configuration (1 hot wall, the five others cold), a laminar stable regime of the hot boundary layer was observed at unexpectedly high Rayleigh numbers.

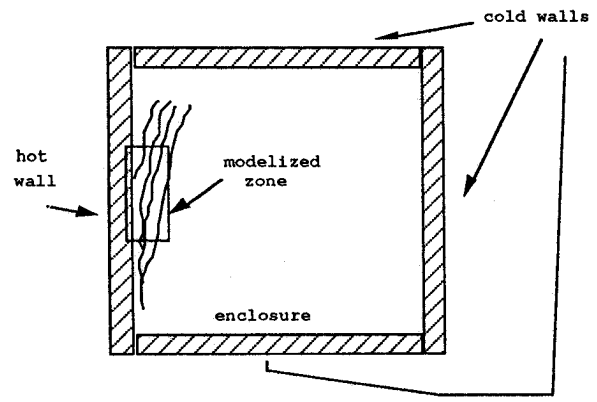

Fig. 5

The modeling process would here aim at assisting experiment analysis and gaining an intelligence of flow stability.

The ZOOM simulation proceeds as follows : the modelized domain includes a part of the conductive wall connected to a thermostat and a fluid strip of the laminar dynamic layer. Experimental datas are used to define mean cell state variables on the surroundings of domain.

Fluid is partitionned in 2D meshes, yielding convectives cells with five state variables corresponding to mass, energy, momentum and angular momentum. For instance, volumic mass ρ_α, energy ε_α and vertical momentum $q_{z\alpha}$ state variables obey equations (Ω_α is cell volume, g is gravitationnal acceleration, c_0 is sound velocity):

$$\Omega_\alpha \, \partial_t \, \rho_\alpha = \sum_l M_l$$

$$\Omega_\alpha \, \partial_t \, e_\alpha = \Omega_\alpha \, g \, q_{z\alpha} + \sum_l W_l$$

$$\Omega_\alpha \, \partial_t \, q_{z\alpha} = \Omega_\alpha \, g \, \rho_\alpha + \sum_l Q_{zl}$$

The various exchanges are described by means of relevant fluxes. For wall-fluid exchanges, specific heterogeneous transfers are used. Some of the relevant associated transfer definitions are :

$$M_{l,\text{vertical}} = S_l \, q_{zl}$$

$$Q_{zl} = S_l \, c_0^2 \, \rho_l$$

Modeling of a Capillary Pump Loop (CPL)

Capillary pump loops are two phase devices used for satellite temperature control : they may transfer a few kilowatts over distances of about ten meters (Ku, Kroliczek and McIntosh, 1987). The example presented here is based on a study of CPL use for earth based solar heating to be presented at ISES 91 Conference.

The system is driven by the pressure jump due to capillary forces at the meniscus existing at the surface of a liquid saturated wick. The main physical process in this device is thus the fluid vaporization at the wick surface : it is both the heat source and the motor of the loop.

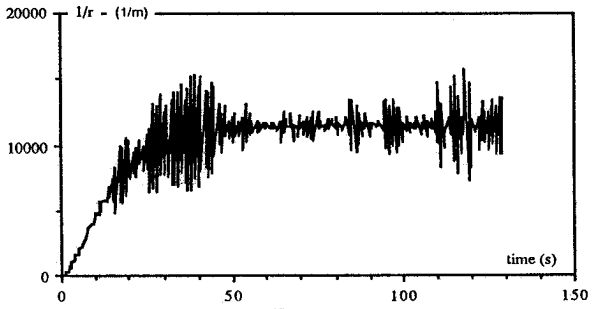

Fig. 6

The modelization purpose is to study this physical process : a detailed transient model of the evaporator has been developped. For instance, the meniscus radius for a steplike input power and a null pressure head is displayed on Figure 6. The sharp variations are of numerical origin : they are due to large coupling coefficients leading to very stiff problems.

The other parts of the loop (vapour header, condenser, liquid return header) have been modelized using a steady state model : the loop is partitionned in cells (one state variable : the average pressure) linked by mass transfers (one transfer variable : mass flow rate) ; the model equations are based on pressure drop correlations.

Heat and Mass Transfer in the Soil

Heat and mass transfer in soil, and their coupling with buildings, are processes belonging to a class of exchange phenomena nearly absent in present BPSA tools in spite of their importance in building pathology.

As a first test bed for the TEF/HED functionnalities, we choose a simple monodimensionnal treatment of the coupled heat and mass transfer processes in a soil whose surface is sollicitated by atmospheric fluctuations, its deeper layer beeing in contact with a ground water table.

The basic physical model is Philips and Devries' (1957) ; an implicit centered finite difference scheme was used. Assumptions, existence and unicity of solutions as well as asymptotic stability are detailed in (Bel Hadj Salah, 1989, 1990).

Goodness of coupling test. The first efforts for testing the resolution process has been to check the validity of the TEF coupling method, by a triple comparison :

- a one domain ascending descending direct method,
- four domains, no nesting,
- four domains and three families (cf Figure 7)

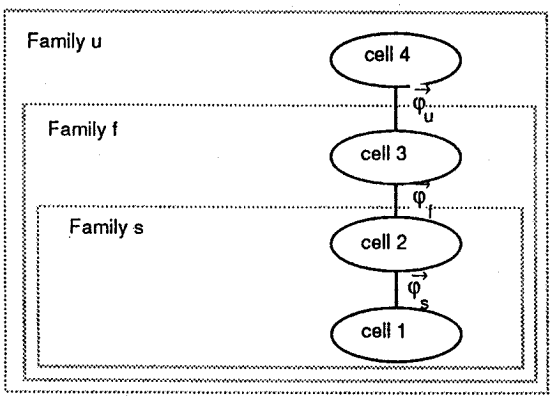

Fig. 7

The results are good, even for the most severe tests corresponding to a constant rain flux on the surface (0.536 kg/m^{2}s), creating a humidity front progressing down until it reaches the asymptotic state resulting in the equilibrium with the humidity coming from the deep water table. The soil and the water flux correspond to the experimental work by Vauclin and others (1979).

The differences between the single domain solution and the domain decomposed in four cells enclosed in three nested families are not above the lower significant digit resulting from the tridiagonal matrix inversion algorithms (Bel Hadj Salah, 1990).

Specific evolution of elementary models of the decomposed soil system. One important aspect of submodeling is that the a priori knowledge of the system can be used to adapt localy a generic model to restricted conditions, allowing numerical simplifications.

In the present case, it is recognizable that the dynamics changes from layers close to atmospheric sollicitations (time constant of a few minutes), to deep layers slowly varying in the season. This dynamic heterogeneity between models is often met in the whole building process, which increases the interest of a "time-nesting method" for practical calculability and as an important information for the intelligibility of systems.

Note that large time steps open numerically the possibility of large mesh sizes resolution, which enhances the computer time reduction without loss of precision on the influence of the deep ground on the building. A 2D version test is under development.

NEW TOOLS

Time Nesting

A particular aspect of the phenomenological heterogeneity is the complex dynamic structure of the models. To keep on the same field example, the characteristic times span from a few seconds (convection, control) to a few weeks (ground influence). With an homogeneous time step technique, the simulation algorithms have to take the lower adequate time step even for very slow phenomena, leading to unrealistic tools.

We have developped an heterogeneous time step method based on TEF development. The main idea is that long time constant (LTC) objects may be considered as linear, slow varying systems, over time intervals much larger than the time step used for the short time constant objects. More specifically, the LTC objects being grouped in an LTC family(s), the matrices associated to these objects will be considered as constant from time t to t+nδt.

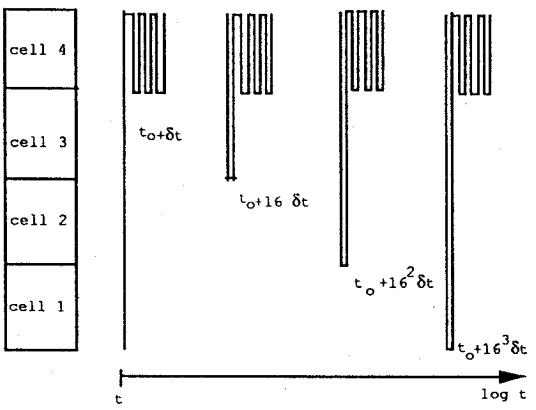

Fig. 8

The algebraic TEF developments have been presented in the previous paper (Bel Hadj Salah and others, 1989).

The resulting solving process is sketched in Fig. 8 where it can be seen that LTC families and objects are not

calculated every steps. The remarkable fact is that this computing time reduction does not destroy the basic coupling information of TEF.

The 1D case study with only 2 levels of time nesting demonstrated a factor of 2 gain in computer time without any loss in precision. This factor increases with the deepneth of the nesting and the dimensionality of the problem.

Regularization

Quite often, for physical reasons, the coupling coefficients will spread over a wide interval, resulting in a problem too stiff to be solved directly. It may even be impossible to compute the coupling matrix because of the singularity of some cell equation.

Whatever the cause, regularizing procedures, if any, may act only in transfer space (since ZOOM begins with state variable elimination). Thus, when a problem arises linked to a state variable, it is necessary to create a copy of this variable in transfer space in order to apply the relevant transformation.

We shall consider two cases of regularization: the steady state problem and the large coupling problem.

Large coupling problem. Two techniques apply to this case:

(i) Re-scaling technique. This method applies to the case where a large off-diagonal coupling coefficient $A_{ij} = \frac{1}{\varepsilon}$ has a much smaller symmetrical coefficient $A_{ji} = c$.

Re-scaling of one of the corresponding transfer variables ($\varphi'_i = \sqrt{|\varepsilon c|}\,\varphi_i$) yields new coupling coefficients such that :

$$|A_{ij}| = |A_{ji}| = \sqrt{\left|\frac{c}{\varepsilon}\right|}$$

In cases where there are several large terms, it is not obvious that such a procedure may apply ; however, in all problems we considered large terms were sufficiently scarse so that this pseudosymmetrization could be achieved ; it yielded a reduction of the condition number of the matrix from K to $\sqrt{K}$. To examplify a simple case with such off diagonal non symmetrized coefficients, let us take couplings occuring in natural convection modeling previously defined.

In the so called sound wave coupling, we have initially the two symmetrical coefficients :

$$\frac{\partial M_l}{\partial Q_{zl}} \approx \frac{S_l}{\Omega_\alpha} \quad \text{and} \quad \frac{\partial Q_{zl}}{\partial M_l} \approx \frac{S_l}{\Omega_\alpha} c_0^2$$

After scaling, we will have :

$$\left(\frac{\partial M_l}{\partial Q_{zl}}\right)_{reg} \approx \frac{S_l}{\Omega_\alpha} c_0 \quad \text{and} \quad \left(\frac{\partial Q_{zl}}{\partial M_l}\right)_{reg} \approx \frac{S_l}{\Omega_\alpha} c_0$$

which gives the expected regularization.

(ii) Asymptotic transfer method. Let us consider the case where there is a large $\eta_\alpha \rightarrow \varphi_i$ coupling and the $F_{\alpha i}$ coupling ($\varphi_i \rightarrow \eta_\alpha$) is of order unity :

$$\delta\varphi_i = \frac{1}{\varepsilon}\delta\eta_\alpha + \ldots \; ; \quad \delta\eta_\alpha = b\,\delta\varphi_i + \ldots$$

$$b \approx 1 \quad ; \quad \varepsilon << 1$$

The $\varphi_i \rightarrow \varphi_i$ coupling is, assuming that (α) is the only contributing cell :

$$C_{ii} = \frac{b}{\varepsilon}$$

This situation is pathological when ε goes to zero, since C_{ii} goes then to infinity, whereas for $\varepsilon = 0$ η_α is frozen, which implies that there can be no coupling via η_α, that is $C_{ii} = 0$. This is a well-known situation in singular perturbation methods. The solution is to use, instead of η_α, an expanded variable $\eta'_\alpha = \frac{\eta_\alpha}{\varepsilon}$. In the TEF case, since we cannot do this in state space, we shall create a new transfer (called A-transfer, A stands for asymptotic) whose variable is $a = \frac{\eta_\alpha}{\varepsilon}$. a and φ_i equations will be :

$$\varepsilon\delta a = \delta\eta_{\alpha,dec} + b\,\delta\varphi_i + \ldots \; ; \; \delta\varphi_i = \delta a + \ldots \; ;$$

which yields the (φ_i,a) sub-block of C :

$$C_{ia} = \begin{bmatrix} 1 & -1 \\ -b & \varepsilon \end{bmatrix}$$

This method has been used in more general cases ; it resulted in a reduction of the condition number of the coupling matrix from K to $\sqrt{K}$.

In the case of steady natural convection, the coupling coefficients are given by the linearized formulas :

$$\delta Q_z = \left(\frac{1}{2} S_l c_0\right)\delta\sigma_\alpha + \ldots \; ; \; \delta\sigma_\alpha = \left(\frac{c_0}{g\Omega_\alpha}\right)\delta Q_z + \ldots \; ;$$

which results in a large $Q_z \rightarrow Q_z$ coupling :

$$C_{QQ} = \frac{c_0^2\, S_l}{2g\Omega_\alpha} + \ldots$$

The asymptotic transfer (equal to $\frac{S_l}{2} c_0^2\, \rho_\alpha$) is then approximatively the pressure force through a cross section of the flow. Finally, the (Q_z,a) sub-block of C is :

$$C_{Qa} = \begin{bmatrix} 1 + \ldots & -1 \\ -1 & \frac{1}{C_{QQ}} \end{bmatrix}$$

which yields the expected square root K reduction.

Steady state solution. Computation of a steady state solution from an unsteady simulation background is one of the current demands within modeling process. Within ZOOM environment, this computation requires few changes on existing processors (for detailed exposure of algebraic technique see Bonin and others, 1989), under the constraint that structural properties of nested operators remain preserved.

The steady state basic equations of cells and transfers are :

$$0 = G(\eta_\alpha, \varphi)$$

$$\varphi = f(\eta, \varphi')$$

It appears that, in the most frequent cases, the first equation leads to a splitting into a regular part :

$$0 = G_r(\eta_\alpha, \varphi)$$

and a singular one:

$$0 = G_S(\varphi) \ (^{**})$$

This situation is very similar to the asymptotic one. So, the state variable $\delta\eta_s$ linked to the singular part will be shifted to transfer space in which they are called K-transfers (K stands for kernel), the regular set of state variables being dealt as usual :

$$\delta\eta_r = \delta\eta_{r,dec} + \mathcal{F}\,\delta\varphi$$

$$\delta\eta_s = \delta k$$

On the other hand, the equations $(^{**})$, in fact the K-transfer definition equation, obviously are nothing but conservation laws for the a cell, such as mass conservation, etc.

If we focus on the previous convective example, the steady state technique starts with equations :

(i) singular part : $(0 = G_s(\vec{\varphi}))$

$$0 = \sum_l M_l$$

(ii) regular part : $(0 = G_r(\vec{\eta}; \vec{\varphi}))$

$$0 = \Omega_\alpha\, g\, q_{z\alpha} + \sum_l W_l$$

$$0 = \Omega_\alpha\, g\, \rho_\alpha + \sum_l Q_{zl}$$

The splitting into regular/singular parts of G here leads to unchanged regular state variable equations :

$$\delta\rho_\alpha = \delta\rho_{\alpha,dec} - \frac{c_0^2}{g\Omega_\alpha} \sum_l \delta Q_{zl}$$

$$\delta q z_\alpha = \delta q_{z\alpha,dec} - \frac{1}{g\Omega_\alpha} \sum_l \delta W_l$$

and a k- transfer dependance of the third state variable :

$$\delta e_\alpha = \delta k_1$$

On the other hand, the first linearized equation can be written :

$$0 = \sum_l \delta M_l - \sum_l M_{l,0}$$

That is merely the mass conservation equation. Ordinary transfers are unchanged.

In the case of the steady state model of the CPL headers and condenser, the state variables are the pressures (p_i) and the transfer variables are the mass flow rates (m_i). The steady cell equation is completely singular: there is one K-transfer per cell.

Cell equation :	$p_i = k_i$
K-transfer equation :	$d_i - d_{i+1} = 0$
Mass transfer equation :	$d_i = f\,(p_i - p_{i+1})$

where f represents a laminar pressure drop correlation or the formula for turbulent flow (see for instance Burtmeister, 1983a). Since the last formula is not linear, an iterative procedure is used.

PERSPECTIVES

TEF and ZOOM evolution in the forthcoming years will be directed towards the development of a mathematical and statistical library yielding more flexibility in physics analysis, the application of ZOOM to experiment analysis, some major software developments (parallel processing, redefinition of objects), the implementation of new modelling methods leading to the modelization of new domains of physics, and some fundamental theoretical studies (coupling theory, thermodynamics of irreversible processes).

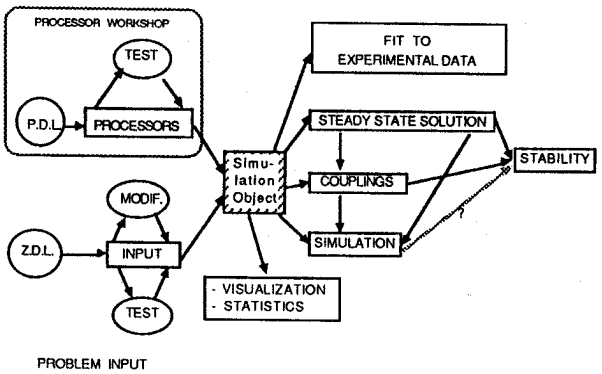

Fig. 9

Technical Developments

The point here is to develop techniques which may take advantage of the nested structure of TEF (error propagation, least Chi-squarred fit to experimental data), or demand some adaptation to TEF structure (computation of coupling matrix singularities, geometrical data processing).

Error propagation will be used for sensitivity or robusness studies ; for instance, in the example of the coupling of a building with the soil, this technique will yield an estimate of the precision needed at various depth in the ground. Coupling matrix singularity knowledge is necessary for stability study. Geometrical data will be handled through a tree structure, onto which the physical objects will point ; it will be used for physics simulation (radiation exchanges) and for C.A.D. interfacing.

Software Developments

Parallel processing. An important consequence of nesting is that computations relative to disjoint families are independent and may be performed simultaneously by different processors. More precisely, the coupling matrices relative to a given family (f) are sums of terms computed within each subfamily (g) of (f) ; hence, each term may be computed indepedently for each sub-family (g), the synchronization occuring when the sums are performed. This property being true for each family at every level of the tree, a great flexibility is offered, allowing massive parallel processing analogously to Charrier and Roman, 1989.

Redefinition of objects. Presently processors span over four worlds : physics, mathematics, numerics, computer science.

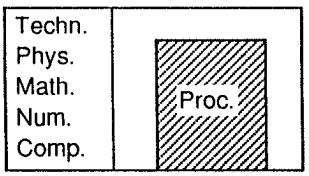

Fig. 10

But there is no structure dealing with these various worlds : processors are one block pieces of software where statements relative to the four worlds are mixed.

Separate mathematical and algorithm libraries will be developped in order to structure the processors among the four worlds. For instance, a conductive cell equation is a first order differential equation ; the processor may call a mathematical first order integrator to compute the $\delta\eta_{dec}$ vector and $\mathcal{F}$ matrix. However, the cell processor itself remains a physical object since it makes use of the physical nature of the variables.

On the other hand, one may consider the creation of cells which would pertain to the technical world (such as windows, rooms, etc.). However, building up such complicated objects would have some drawbacks. For instance, steady state computation and K-trans-fer definition would entail awkward algebraic developments. It is much easier to cluster elementary physical objects into a "technical family" which will represent the macro object (window or room). The structure will be :

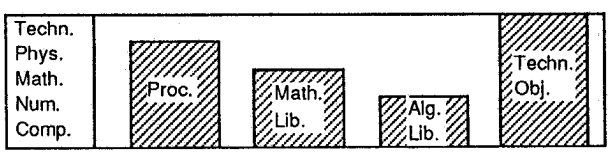

Fig. 11

However, one should realize that the actual objects managed by the ZDL are physical objects and that the technical objects come in only as an added secondary facility.

Physics Modelling

Implementation of new techniques for model development or model transposition in ZOOM. The main features of simulation codes for physical modeling will be their ability to handle a great variety of models and of matching techniques, and also to take into account specific properties of models.

• Model variety : In its present form, ZOOM cannot handle two- or three-dimensionnal cells with several thousand nodes : the systematic computation of coupling matrices is too expensive in these cases. The use of conjugate gradient method or local relaxation will bring the needed flexibility. Two examples are being developped : a 2D Patankar type convection model (few thousand state variables) (Patankar, 1980) and a 3D potential flow model (several ten thousand state variables).

• Matching variety : The exploration of model matching techniques is presently concerned with matching by continuity (used also in the SYMBOL project) and by overlapping (used in the method of matched asymptotic expansion).

• Model specificity : Using T.I.P. (Thermodynamics of Irreversible Processes) or a bond-graph like method would yield coupling matrices with specific symmetry properties. The solver part of ZOOM will be modified in order to take these into account.

T.E.F. application to physical modeling. Using TEF induces the building up of new model. Studying the characteristic features of these models and the new concepts they may bring forward is one of our major tasks.

An example where TEF actually changes the very deep structure of the model is given by the Matched Asymptotic Expansion method applied to free convection. An attempt to define interface variables and coupling equations showed that a model based on a perturbed Schmidt-Beckman velocity profile (Burtmeister, 1983b), with its exponentially small longitudinal velocity at infinity, could not be coupled to any external flow model.

Then modeling may proceed in only two ways : either consider that the boundary layer universe is closed and work exclusively within it, or use as reference profile a model where the velocity at infinity is non zero.

CONCLUSION

The ZOOM software has been developped in close contact with physics research in buildings : it is permanently fitted to problems occuring in the research field, where it brings up new modelling concepts. Hence its main features and its evolution are oriented toward maximum adaptability, in order to enable the user to deal with the greatest variety of building performance analyis problems. Simultaneously, it offers the widest range of investigations, going from global system analysis (coupling analysis) to very local scruting of individual variables.

These functionnalities are obtained thanks to physics oriented modelling, to a clear definition of the partitionning/interfacing process, and to a strong emphasis on interface objects.

The main tool is the nesting procedure. Through grouping components in families, it yields the possibility of using families as elementary objects and, simultaneously, to exhibit their internal functionning.

REFERENCES

ALMETH (1991): The model coupling problem : methods used in some Building Analysis Tools and the ALMETH Propositions. Paper 107 of this Conference.

ARC Convection Naturelle dans l'Habitat (1986). Bilan et perspectives. PIRSEM-CNRS Report, Paris, France.

Augenbroe G., L. Laret (1988). COMBINE Pilot Study Report. CSTB report TTA/MGL-1023/NB, Sophia-Antipolis, France.

Bel Hadj Salah, H., L.M. Chounet, J.L. Dufresne, J.Y. Grandpeix, J.L. Joly, A. Lahellec (1989). An heterogeneous time stepping technique for the Transfer Evolution Formalism. Proceedings ESM 89, Rome, Italy.

Bel Hadj Salah, H. (1990). Modélisation des transferts couplés de chaleur et de masse dans le sol, orientée vers le calcul des déperditions thermiques des bâtiments. Thesis, Université Paris Sud, Orsay, France.

Bonin, J.L., J.Y. Grandpeix, A. El Hasnaoui, and J.L. Joly (1987). Coupling analysis in building thermal simulation: the ZOOM program. Proceedings of ISES., Hamburg, Germany.

Bonin, J.L., J.Y. Grandpeix, A. Lahellec, J.L. Joly, V. Platel, and M. Rigal (1989). Multimodel simulation: the T.E.F. approach. Proceedings ESM 89, Rome, Italy.

Burtmeister, L.C. (1983a). Convective Heat Transfer. J. Wiley, New-York, N-Y : 493.

Burtmeister, L.C. (1983b). Convective Heat Transfer. J. Wiley, New-York, N-Y : 511-517.

Charrier, P., J. Roman (1989). Algorithmique et calculs de complexité pour un solveur de type dissections emboîtées. Numerische Mathematik, 55 : 463-476.

Dubois, A.M. (1990). Eléments de spécification d'un environnement avancé de modélisation et simulation. Application à la thermique du bâtiment. Thesis, Université de Nice-Sophia-Antipolis, Sophia-Antipolis, France : Chap. 6 and 7.

Ku, J., E.J. Kroliczek, W.J. Raylor, and R. McIntosh (1986). Functional and performance test of two capillary pumped loop engeneering models. AIAA Thermophysics and Heat Transfer Conference, Boston, Massachussets.

Ku, J., E. Kroliczek, and R. McIntosh (1987). Capillary pumped loop technology development. Congrès International Caloducs, Grenoble, France.

Patankar, S.V. (1980). Numerical Heat Transfer and Fluid Flow. Hemishere Publishing, Mc Graw-Hill, New-York, N-Y.

Philip, J.R., D.A. Devries (1957). Moisture movement in porous materials under temperature gradients. Trans. Ann. Geophys. Union, 38, 222-232.

Vauclin, M., R. Haverkamp, G. Vachaud (1979). Résolution numérique d'une équation de diffusion non linéaire. P.U.G., Grenoble, France