Exploring an Intelligent Front End for Building Energy Simulation

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ABSTRACT

The need - stemming from comfort, environmental and energy considerations - for tools which enable an integral approach of building and heating, ventilating and air conditioning systems is described.

Building energy simulation is an important technique in this respect. This technique is described in its wider context of Computer Aided Building Design. Then a brief overview is presented of the state-of-the-art, current status and future developments in the field of building energy simulation.

On the user side of the increasingly sophisticated building energy simulation environments, new problems occur deriving from the conflict between the increasing complexity of the modelling system and the users’ desire for a simple, straightforward and intuitive interface.

An Intelligent Front End (IFE) based on Intelligent Knowledge Based System, and Human-Computer Interface techniques, is a promising development in this area. After some background information, and a description of users and IFEs, the ESRU research prototype IFE is outlined. The current status and future work are indicated. Finally some conclusions are indicated.


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1. INTRODUCTION

The dynamic thermal interaction, under the influence of occupant behaviour and outdoor climate, between building and heating / cooling and ventilating system is still difficult to predict. In practice this often results in non-optimal, malfunctioning, or even "wrong" building / system combinations.

This is not an over-statement as can be demonstrated with examples from our own experience (Hensen 1986, 1987). This concerned predictions and measurements related to an extensive real scale experiment with several types of low-energy houses. With respect to reduction of heat-loss by transmission and natural ventilation through building structural measures, the experiment is regarded as very successful. Without going into any further details, another one of the main conclusions was however that there is definitely a need - and room - for improvement on the plant side and with respect to building / system thermal interaction.

![Diagram](image)

Figure 1 Diagrammatic representation of building and plant

There is a large class of problems for which the complete "system" - as indicated in Figure 1 - consisting of building structure, occupants, heating, ventilating and/or air conditioning (HVAC) system, and prevailing climate must be evaluated simultaneously and as a whole. Other topics belonging to the same problem domain and which definitively also need this integral approach are (in no particular order): Sick Building Syndrome, Building Energy Management Systems, application of passive solar energy, HVAC system and control development and testing, integrated systems (eg floor heating, ice rink, swimming pool), and unusual building / system combinations which may occur for instance when a historical building finds a new destination (eg a church being converted into a multi-purpose centre) or in case of relatively new
developments like atria.

Up to now the building design process is more or less sequential; first the building is designed and subsequently the heating/cooling/ventilating system. The dynamic thermal interaction is usually left out of consideration completely. Thermal comfort requirements are commonly reduced to required air-temperature, neglecting other important thermophysiological environmental parameters like radiant temperature and air velocity. For system design, usually only extreme internal and ambient conditions are considered.

It is obvious that this cannot be the right approach for either thermal comfort or for energy consumption. So it is clear that there is definitely need for tools which enable an integral approach of the building and its HVAC systems as a whole.

2. BUILDING ENERGY SIMULATION

One of the techniques which may be employed to achieve this, is modelling and simulation. Modelling is the art of developing a model which faithfully represents a complex system. This can be a physical (scale or full size) model, some (eg electric) analogon, or a numerical model. Simulation is the process of using the model to analyze and predict the behaviour of the real system.

Computer modelling and simulation have become indispensable engineering techniques in the fields of design (eg of buildings, plant configurations, and on the component level) and operation (system control, understanding, and interaction). The main reasons are the vast advantages - over for example experimentation - with respect to:

- economy; in an increasing number of cases, simulation is faster, better and cheaper than experimentation,
- prediction; allows analysis of a (model of a ) system which does not yet exist, and
- education; models are easily adapted, inexpensive to operate, able to simulate adverse conditions and may also serve as an aid in communication.

It should be noted though that simulation and experimentation are complementary; experimentation to discover new unknown phenomena or for validation purposes, and simulation to understand interactions of the known components of a system.

In the current context, modelling and simulation is used for predictions to help solve real world problems regarding buildings and the HVAC systems which service them. The building in question may be an existing structure, a proposed modification of an existing structure, or a new design.

2.1. The CABD Context

Since the early 1960’s, the use of computers in the field of building design - ie CAD (Computer Aided Design) which was only later specified to CABD (Computer Aided Building Design) - has been increasing steadily (Rooney and Steadman 1987).

The design process itself is very complicated, as may be concluded from the vast amount of work aimed at establishing models of the process of design. As Butera (1990) points out, the architectural design process may even be approached using principles from the so-called "deterministic chaos" theory. The complexity and the diversity of parameters to be taken into account leave large opportunities to chance in identifying the design optimum. The optimum may be regarded as a "strange attractor" in this context.

Due to its complexity, general software to aid in the design process, is much less developed and received much less attention than draughting and design process management tools.

There is however one activity throughout the design process which has received much attention: building performance appraisal. Powerful, computer-based models were created to assess cost, performance and visual impact issues in design: from life-cycle cost estimates at the design proposal stage, through realistic visualisations of the design, to comprehensive evaluations of building energy and environmental performance.
In terms of research, up to now the majority of activity is directed towards proving the system and towards the acquisition of application knowledge. In the field of building energy simulation for example, a number of projects concerned with model validation have been carried out. Currently there are indications that the building energy simulation research activity is broadening in its scope (see eg Augenbroe and Laret 1989, and Clarke and Maver 1991). More effort is being expended on human-orientated CABD, through expert systems, HCI research and the like (eg Clarke and Rutherford et al. 1989). There is also a greater tendency to approach the problems underlying CABD in a multi-disciplinary, inter-institutional manner (e.g. Clarke and Hirsch et al. 1986, Clarke and Irving et al. 1988, and Augenbroe and Winkelmann 1990). This is also reflected in the recent formation of building analysis organisations: International Building Performance Simulation Association (IBPSA 1989), Building Environmental Performance Analysis Club (BEPAC 1989) in the UK and Building Analysis Groups (BAG) in the Benelux.

Clarke (1988) points out that CABD is not a remedy for all difficulties. At worst it is an automation of much of the mechanics of design. At best it allows an evaluation of the relationships inherent in a given design hypothesis. At present, the application of CDBD is expensive, in terms of required human resource, and time consuming. In the near future the profession will probably experience a skills shortage. In the longer term however, with further advances in technology, application knowledge and education and training, CDBD might bring important changes in the design process, involving de-skillling and the breakdown of professional boundaries. CDBD could well become the common denominator of all parties involved in the design process, through some future IIBDS (Integrated Intelligent Building Design System). This will lower or even remove inter-professional barriers and improve the quality of the end product, the building.

As indicated, CDBD is an evolutionary process which is characterised by several strong interrelations between quite different issues. For example, the level of application of energy simulation is as much a function of education and training as it is of hardware and HCI. Of course, CDBD must also be regarded in the light of other technological and other developments which are taking place around us. That is, CDBD will certainly become integrated in the "office of the future" which might offer multi-media personal work environments, incorporating integrated CAD/CAE (Computer Aided Engineering) features. One important issue not yet mentioned above is that of politics. There is a definite trend towards requiring that specified conditions must be achieved during the operation of buildings as well as in the design of buildings (as in ASHRAE's 1989 standard on ventilation and air quality, and towards setting up "responsibility chains", ultimately making a design team liable for the performance of the end product (as implied in for instance ASHRAE's (1989) guideline for commissioning of HVAC systems). It could well be that if these trends are followed and accepted by the building industry, such issues will become major catalysts in the evolution of CDBD.

Building energy simulation must be placed within this evolutionary context. Contemporary energy models are an important improvement compared with the traditional methods they replace. However, there are still several important developments which must be undertaken before valid, easy to use models can be delivered to the design profession.

2.2. State Of The Art

Building energy modelling and simulation is part of an evolutionary process in the field of building design tools. Table 1 (from Clarke 1988) summarizes one view of the evolution of these design tools, from the traditional via the present day simulation approach to the 4th generation tools by the late 90s.

In terms of Table 1, the present work (as described in Hensen 1991) must also be regarded as a 3rd generation approach.

Early work in 3rd generation approaches, focussed on the relation between building design and energy consumption (eg Clarke 1977, Bruggen 1978), or between building design and thermal comfort (eg Lamers 1978). In this and in later work (eg Hoen 1987), the auxiliary system was still more or less regarded
Table 1 Evolution of building energy models (Clarke 1988)

<table>
<thead>
<tr>
<th>Generation</th>
<th>Handbooks orientated</th>
<th>Indicative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st generation</td>
<td>Analytical in formulation</td>
<td>Application limited</td>
</tr>
<tr>
<td></td>
<td>As simplified as possible</td>
<td>Difficult to use</td>
</tr>
<tr>
<td></td>
<td>Piecewise in approach</td>
<td></td>
</tr>
<tr>
<td>2nd generation</td>
<td>Dynamics important</td>
<td>Feedback loop</td>
</tr>
<tr>
<td></td>
<td>Still analytical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Still piecemeal</td>
<td>Increasing integrity</td>
</tr>
<tr>
<td></td>
<td>Suitable for low-order problems</td>
<td>vis-a-vis the real world</td>
</tr>
<tr>
<td></td>
<td>with time invariance</td>
<td></td>
</tr>
<tr>
<td>3rd generation</td>
<td>Field problem approach</td>
<td></td>
</tr>
<tr>
<td>(current generation)</td>
<td>requiring numerical methods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrated view of energy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sub-system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Suitable for high-order problems</td>
<td>Leading to</td>
</tr>
<tr>
<td></td>
<td>with time variation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat and mass transfer considered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better user interface and partial CADD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>integration</td>
<td></td>
</tr>
<tr>
<td>Next generation</td>
<td>Full CADD integration</td>
<td>Predictive</td>
</tr>
<tr>
<td></td>
<td>More advanced numerical methods</td>
<td>Generalized</td>
</tr>
<tr>
<td></td>
<td>Intelligent knowledge-based</td>
<td>Easy to use</td>
</tr>
<tr>
<td></td>
<td>Object-orientated software architecture</td>
<td></td>
</tr>
</tbody>
</table>

as a given boundary condition instead of as a variable. These workers emphasized the building side of the overall problem domain, while others (eg McLean 1982, Murray 1984, Tang 1985, Lebrun 1988) focussed more on the plant side.

In the former approach the influence of the plant system is more or less neglected by over-simplification of the plant. In that approach it is common practice to base the estimation of energy consumption on some presumed, imposed indoor air temperature profile. In the latter approach the complex building energy flow paths are usually grossly simplified, and the building (or each building zone) is commonly regarded as just another component which in this case imposes a thermal load on the plant.

Although justifiable at that time, it is now felt that neither approach is preferable for the majority of problems which are affected by the thermal interaction of building structure and auxiliary system.

For the present work, we had the choice of starting from scratch (as the precursory work indicated above, had become obsolete due to computer science department policies) or to start from what already existed in the international research community. The latter option was chosen.

Then there was the choice of starting from a plant orientated simulation environment like TRNSYS (SEL 1988) and HVACSIM+ (Clark 1985), and enhancing this towards the building side of the overall problem, or alternatively, working the other way around, and start from an established building energy simulation environment and enhance this on the plant simulation side of the overall problem domain.

We opted for the latter approach, one reason being that this coincides better with the building engineering background of our unit.

2.3. The ESP^R Simulation Environment

The decision to work with the ESP^R building energy simulation environment, was based on (among others) the following arguments:

Environmental Systems Performance, Research version
- it is based on state-space equations and a numerical processing scheme representing all building heat
flux exchanges and dynamic interactions. Central to the model is its customised matrix equation proces-
sor which is designed to accommodate variable time-stepping, complex distributed control and the treat-
ment of "stiff" systems in which time constants can vary by more than an order of magnitude. It allows
multi-zone processing and has an infrastructure supporting complementary program modules covering
data input, graphical results display and interrogation, climate and construction database management;
the computation of shading, solar beam tracking, view factors and window spectral behaviour; and facil-
ities for comfort assessment, condensation checks, and the like.
- it is clearly a research orientated environment, with the objective to simulate the real world as rigorously
as possible to a level which is dictated by international research efforts/results on the matter in question.
Step-by-step it will be enhanced/improved. It seeks to incorporate the latest state-of-the-art techniques
to a feasible level, which means that the specific technique must be more or less generally applicable and
there must be a certain amount of international consensus about the technique.
- sets out to take fully into account all building & plant energy flows and their inter-connections. It also
offers the possibility to assess building & plant performance in terms of thermal comfort. Thus it is
specifically suited to do research on subjects in which inter-weaving of energy and mass flows plays an
important role.
- source code is available and well accessible, because the system is highly modular in nature and offers
important features like inbuild trace facilities.
- the system is well documented: it is heavily commented within the code itself, there is an extensive man-
ual which is updated on a regular basis (Clarke and Hand et al. 1991), and there is also comprehensive
background material available (eg Clarke 1985).
- the system has been - and still is - the subject of various international validation programmes; for exam-
- the system offers extensive graphics facilities.
- because it runs in a UNIX operating system environment, all UNIX strengths (hardware independence and
standardization, multitasking capability, hierarchal file system, powerful command shells) and extensive
range of utilities (for software engineering, numerical techniques, documentation, data retrieval, data
reduction, data analysis, etc) are "automatically" available to anyone using the system.

It should be noted though - and this is clearly not meant in any negative sense - that because of its
research orientated and evolving nature, the ESP$^R$ energy simulation environment is not as slick as one
would demand of for instance a commercial package. Instead the system expects - and deserves - a pro-
active approach of the user.

2.4. Background

Having been developed since 1974 (involving many person years of research), by 1985 ESP was selected
as the European reference model in the field of passive solar architecture (CEC 1986). The system's
validity was further tested in now completed validation projects (Bloomfield 1987, Lebrun and Liebecq
1988), and in the recently completed passive solar project PASSYS (Gicquel and Cools 1986, CEC 1989)
in which various centres throughout Europe were rigorously testing the system against test cell experi-
ments.

ESP$^R$ originates from and is controlled by ESRU (Energy Simulation Research Unit) at the University of
Strathclyde. Several research groups are now working with the system. For example, in North America
the model is established at Lawrence Berkeley Laboratory, at the National Institute of Standards and
Technology (formerly: National Bureau of Standards) and at the Northwest Pacific Laboratory. And in
Europe, it is operational at lead research centres in each of the EC member states.

Recently a communication platform (in the form of an conferencing facility using electronic mail) was
established aimed at keeping colleague researchers informed about ongoing and planned developments,
system related publications, new results, emerged problems, upcoming releases, etc. One of the main
benefits of this are improved efficiency ie. increased output of the researchers, but it is quite easy to see many more advantages. At the moment, 34 researchers from 16 countries are included in the distribution list.

Starting from such an established and internationally recognised platform offers vast advantages for any individual research group. The most important ones are:
- economical; due to the complexity involved and the sheer size of the software to result, it is practically impossible for any (small) research unit to develop and maintain such a system as an independent product,
- academical:
  - as an individual group it is not necessary to have expertise in all areas,
  - areas not addressed within a specific research project will still be state-of-the-art,
  - results transfer to the international research community is implicit and therefore very efficient,
- practical; as more people are using the system, any bugs or flaws are likely to surface - and be solved - sooner.

2.4.1. Current status

![Diagram](image)

Figure 2 Diagrammatic representation of the ESPR simulation environment

Figure 2 shows a diagrammatic representation of the various actors, components, and interactions currently involved in the ESPR simulation environment. For more comprehensive descriptions of the system, the reader can be referred to (Clarke 1985, Clarke and Hand et al. 1991, Hensen 1991), and numerous topical papers and other publications.

The core of the system is the simulator or simulation engine (to the users this is currently known as bps). The simulator performs the actual simulations using a product model. The latter is the complete collection of data describing the model; ie in the current context: building, plant, fluid flow network, occupancy, site, outdoor climate, etc.

The user side of the system is formed by the users who, via a user interface, may define and act on the product model using various tools. The tools making up the user interface, generally fall into one of the following three categories:

* As indicated by the dots in the figure, there may be tools which fall between these categories.
- **intelligent design assistants**: high-level user interfaces utilizing state-of-the-art Information Technology techniques, i.e., an 'intelligent front end' like the IFe;
- **dedicated project tools and productivity aids**: e.g., the general project manager *prj*; database managers *con* for constructions, *pro* for event profiles, *clm* for climate, *pdb* for plant components; specialized pre-simulation analysers like *mrt* for view factors, *shd* for external surface shading analysis, *win* for spectral analysis of multilayered window systems, *ins* for internal surface insolation prediction; and the simulation results analysis module *res*;
- **generic tools**: e.g., as provided with the operating system (text editors, file system managers, etc.), assembled from various operating system tools (i.e., shell scripts), or provided by 3rd party suppliers (either public domain like *gritool*, *touchup*, and *psraster*, or proprietary software like *ww*, *ten*, and *ralbrowser*).

The developer side of the system is formed by the developers who, via a developer interface, introduce new or change/expand existing parts/modules of the simulator. Again, the tools making up the developer interface can also be divided into three categories:

- **intelligent development environments**: high-level developer interfaces utilizing state-of-the-art Information Technology techniques, i.e., an object orientated energy kernel system like the *eks*;
- **dedicated simulation modules**: which are specialized in simulating a particular aspect of the overall problem domain like for example the existing modules *blt* for building form and fabric, *plt* for plant systems, *mfs* for fluid flows, the modules under development for combined heat and moisture transport, and for imperfectly-mixed room air modelling, and future modules for controls, site, light, etc;
- **generic development tools**: e.g., as provided with the operating system (editors, debugging tools, program verifiers, etc), build from these (i.e., shell scripts), or software engineering tools provided by 3rd party suppliers (either public domain like *toolpack*, *floppy*, and *f2c*, or proprietary software like *forchk*).

The above is merely presented here, because it sketches the context in which *ESP* is 'growing'. It also indicates why more and more people are becoming involved with the (software) development of the system, which itself is becoming increasingly comprehensive and complex.

### 3. Exploring the IFe Intelligent Front End

It may be apparent that while development of building performance evaluation tools as described above will comprise a valuable addition to the building engineer's toolkit, they also create new problems deriving from the conflict between the necessity for the tools to be powerful, comprehensive and according to Van Nes 1991.

As Clarke (1991) points out, the conflict between power and ease of use is further exaggerated by the diversity of the conceptual outlook of the design orientated program users and the technically orientated program developers. And to complete the confusion, there is the subtly different terminology of the various engineering professions.

Particularly at the earlier stages of the design process, there is a need for rapid feedback on the cost and performance consequences of alternative design scenarios. The present system of specialist consultants, while adequate for the detailed design and final specification phases, fails to provide this immediate 'ad hoc' advice.

The current, and laudable, trend towards user friendly interfaces carries the risk of negating the power and flexibility of models by restricting the interaction to the lowest common denominator user level. Two of the major fundamental problems, the quantity and nature of the data being manipulated and the expertise and conceptual outlook required of the user, apply to a greater or lesser extent to all models. Although overcoming these problems will ultimately require truly intelligent systems, recent advances in Intelligent Knowledge Based System (IKBS) and Human-Computer Interface (HCI) techniques offer some scope for
medium term alleviation. Using these techniques it is possible to construct a user interface which incorporates a significant level of knowledge in relation to building description - in the face of real world uncertainty and realistic performance assessment methodologies. Such a system would direct a user's line of enquiry, allowing 'What do you suggest?' and 'Why do you ask?' type responses. It would also be expert enough to devise an appropriate performance assessment methodology and to coordinate model operation against this.

One of the projects underway in this area is described by Clarke et al. (1989). Their work concerns an attempt to solve the above problems by developing an IFE for building performance appraisal in general; this particular system is termed IFe to distinguish it from the general case. It is in this context that a 5.5 month work-stay was arranged at ESRU, during which period the IFe was explored in depth. The following paragraphs are adapted from Clarke and Mac Randal (1990).

3.1. Simulation Model Users and IFEs

One of the main objectives of an IFE in the current context, is to handle the diverse user types that are found in the field of building performance modelling. To do this, the spectrum of users has initially been divided into three stereotypes:

**Designer**
Here the model has, typically, to deal with the earlier stages of the design process, characterised by high level, abstract concepts, incremental and exploratory definition of the issues, lack of focus (from the system viewpoint), tentative data, missing information and so on. What is required is a feel for the building performance, notification about potential trouble spots and information on the consequences of alternative design decisions.

**Engineer**
Complementary to the above, once the overall design decisions have been made, there is a wealth of hard concrete information and a set of well defined objectives (albeit within each objective, there is a "designer" type activity to be carried out). The task thus becomes the utilisation of appropriate elements of the appraisal system to provide hard information upon which to make engineering decisions and provide feedback on the performance of the proposed building. Normally, the appraisal system matches this task quite well, but the user does not want to have to deal with the complexity and obtuseness of specific computer programs.

**Modeller**
Here the user is probably very familiar with the appraisal system and requires almost direct access to its functionality. The only help required is, perhaps, straightforward assistance with data preparation, both by providing standard data and by providing sensible default values to minimise data input.

Because the requirements of these three user types were kept firmly in mind during its design stage, the IFe can potentially handle any desired user type. Unfortunately, the resources available only permitted the second category to be implemented in any great detail.

Another, orthogonal categorisation is based on the user's level of expertise. In the field of building performance modelling, experience to date tends to classify users into two categories, which differ substantially in terms of requirements:

**Expert**
As usual, the expert is concerned with speed and flexibility of input, direct control of the operation of each module of the system and access to all the resultant output in a structured but flexible manner.

**Novice**
The novice, also as usual, wants a clear and coherent interface, where the system provides guidance on options and their implications, error trapping and recovery, and presents results in an easy to understand manner. It should be noted that the novice is often an expert in his own field; the term is here used only in the context of computer modelling.
As well as distinct classes of user, there are 3 distinct facets of the modelling process, each raising its own set of problems for the user. These are data input, model control and result interpretation.

Data Input
One of the basic difficulties facing current designers is the sheer quantity of data required to describe a building and manipulate a model. Not only is gathering this data a time-consuming task, but frequently the data has not yet been specified, as is the case at an early design stage. Traditional interfaces tend to offer little help in generating sensible defaults. Also, due to the complex interrelationships, ensuring the integrity of the data can demand very high levels of understanding of the model’s theory and mode of operation. Without this understanding, the importance, and hence the required accuracy, of an individual piece of data is very difficult to judge.

As well as the question of ‘what’, there is also the problem of ‘how’ to input such a large quantity of highly inter-related data. The various factors associated with data acquisition, together with the user’s often idiosyncratic conceptualisation of the inter-relationships, tend to conflict with the rigid question/answer style of input common to many contemporary programs.

Model Control
Generally, control of the model does not require sophisticated user interaction. The major difficulty is the selection of the computational parameters to produce a sufficient quality and quantity of output to allow a meaningful appraisal of performance - in other words what is the most appropriate performance assessment methodology.

For the novice, a lack of understanding of the implications of the selections being made can lead to confusion, or even erroneous deductions if the output data is inadequate.

Result Interpretation
It is here that the requirements of the novice and expert differ most. The expert will be trying to detect patterns in, and relationships between, the different building parameters, in an attempt to isolate the dominant causal factors. To do this, all the data generated by the simulation has to be available and capable of being displayed in juxtaposition with any other data.

The novice, on the other hand, merely requires a concise summary of performance, preferably in terms of those parameters which are most meaningful to the design team and client. Unfortunately, due to the nature of the program’s output, the novice may experience difficulty in relating poor performance to the design parameters under her/his control.

3.2. The ESRU IFe in Outline
The objective of ESRU’s project was to develop a research prototype IFE for computer-aided building performance modelling in general. The goal was to design a machine environment which could act as an expert consultant to assist the user in the problem description phase, recognise her/his appraisal wishes, commission computer analyses and report back on performance; all in terms which are acceptable to the given user type and design stage.

To achieve these goals, the IFe has become an intricate synthesis of user modelling, HCI techniques, contextual knowledge manipulation and the interface to the possible performance prediction models at its back-end. In essence, the IFe is a generalised machine environment - a kind of intelligent user interface management system - which can define the mapping from any user’s conceptual model of a domain (here building performance assessment) to the data requirements of any performance prediction model, simplified or detailed.

The IFe system is built from several cooperating modules organised around a central communications module, the Blackboard, to facilitate multiple use of information. These modules run asynchronously and can examine the Blackboard for information, and post results back to it. Figure 3 shows the IFe
architecture.

Figure 3 Diagrammatic representation of the IFe architecture

The modules include:

- A **Dialogue Handler** to converse with the user in a manner which is tailored to her/his conceptual class, level of experience and stage reached in the design process.

- A **Knowledge Handler** to verify user entries and, by inference, to complete the building description to the level required by the target application program (for example the ESP* building energy simulation environment (Clarke 1985, Clarke et al. 1991) is the target program in the IFe prototype).

- A **User Handler** to track the user's progress and ensure the system responds in an appropriate manner.

- An **Appraisal Handler** to coordinate the performance assessment methodologies.

- A **Data Handler** to create, from the information supplied by the user and the knowledge handler, the building description as required by the application program(s) to which the IFe is interfaced.

- An **Application Handler** to orchestrate an application program against the selected performance assessment methodology and to feed it its required building description data.

The functions to be handled by the IFe therefore include conversing with the user in the appropriate terminology (the Dialogue Handler); generating the description of the building (the Knowledge Handler); collecting, organising and storing this data (the Blackboard); generating the program-specific input data-set (the Data Handler); generating the program-specific control inputs (the Appraisal Handler); and invoking the targeted application program (the Application Handler).

### 3.2.1. Status of the IFe

At the present time, a research prototype IFe is operational on a Sun workstation environment (Sun 3/60 and Sun SPARCstation under SunOS Release 4.1.1). Specifically, the following has been achieved.

- The blackboard is fully developed and is able to interface with any number of autonomous clients.

- The user dialogue module is based on a generalised forms manipulation program, designed to operate on bit-mapped screen technology under X-Windows or Sun's SunView window environment. Its function is to manipulate a set of forms which correspond to a particular user conceptualisation.

- The knowledge handler is implemented as a Prolog inference engine. Its mission is to control the forms interface, directing the dialogue session and responding to the user's inputs and requests for help.
A form-set corresponding to one particular user conceptualisation (a moderately proficient Engineer) has been developed and the knowledge bases, matched to this conceptualisation, created.

The Appraisal, Application and Data Handlers have been configured in a form suitable for (but not restricted to) use with the ESPR simulation environment and the requisite scripts installed.

The IFe system exists as a research prototype which will be refined in the coming years. As an aid to this refinement process, it is the system authors' (ie Prof. Clarke's) hope that others will attempt to apply the system, to their particular end user types and application programs.

Currently there is only one user conceptualisation available, corresponding to an individual who is relatively experienced in energy modelling, though several more have been proposed (Clarke et al. 1989). This conceptualisation corresponds to a moderately computer literate engineer and is used in the IFe research prototype as an illustrative example to demonstrate the technique of conceptualisation installation. The targeted application, which defines the scope of the building description as held on the Blackboard, is the ESPR system.

3.2.2. Future Work

The IFe has been conceived and progressed to the research prototype stage. Given the complexity of the system, it will require a further R&D effort to evolve the IFe into a robust product which can be used routinely by others to create intelligent interfaces for their particular applications and user types. In particular the IFe could be refined by improving the efficiency and flexibility of the knowledge handling, conceptualisation entry and data manipulation functions. In the first two cases this could be achieved by the development of software tools to assist in knowledge base creation and conceptualisation entry. This would reduce the level of computing science expertise required and so allow a greater number of application specialists to work with the IFe directly. In the last case a simple schema definition language could be defined which is capable of handling the requirements of the IFe as well as the STEP data exchange standard (ISO 1988). The Blackboard would then be enhanced by the addition of a mechanism to search the schema, so that clients can request specific data without specifying where in the schema it is stored. This would greatly increase the efficiency with which new or existing clients could be serviced, and by reducing the need to know about the data structuring used by other clients, will further improve the IFe's modularity. This, in turn, would ensure that major new components, such as new appraisal methodologies or user conceptualisations, could be added more easily in future.

4. CONCLUSIONS

A research prototype IFE (named IFe) has been developed which enables a human-sensitive approach to building performance appraisal in the context of the multiplicity of models now emerging (from the advanced simulation systems to the regulations orientated structures such as Eurocode).

The principal advantage of an IFE is that it helps users to deal with the varying scientific, engineering and design vocabularies. This should help in the technology transfer process by easing the learning curve associated with the adoption of the new modelling technologies.

By giving the profession access to the power of contemporary and future software systems from a single building description achieved from only the information the user is able to give, the possibility of truly integrated, multi-criteria design appraisal is enabled. This, in turn, will allow the designers to make the necessary trade-offs in the search for an optimum solution and so arrive at more robust designs.

The IFe system is operational within a Unix workstation environment. Several groups throughout the world are attempting to apply and further research it; ie the IFe is currently subjected to a beta test programme. The envisaged way ahead for the system incorporates:

* Work with practicing designers to develop "real" conceptualisations (spectrum of user preferences).
* Interface the IFe to a range of appraisal systems (spectrum of techniques).
* Plurality of advanced engineering software accessible from a single, user sensitive interface.
• Field trials.
• Further technical improvements.

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References


