Multi-Disciplinary Views to an Integrated Simulation Environment

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This paper examines the application of simulation tools to daylighting and heating energy use in the context of what questions the designers wish to ask and what answers they seek. We describe a framework to provide an integrated simulation environment which the designer can use to pose such questions and receive the required answers. While the structure of the integration framework is similar to many comparable projects in the field of integrated environments, we concentrate on the methods required to provide tailorable user-interfaces to the base models. These can be created for any designer. These user interfaces provide views of a building which allow the designers to view and modify the information required for design and analysis, in a form that suits their requirements at various stages of the design process.

Introduction

It is clear that simulation can provide accurate answers to design questions. However, in practice, the application may take too long to set up and run to provide the crucial information at the early design stage when the major building parameters are being established. What designer wishes to take the risk of building a glazed atrium with natural ventilation, when their engineer is advising them that a conventional design solution would only have 10% of the surface glazed?

This paper will examine, through case studies, the application of simulation of daylight and heating energy use to a library (Isaacs and Donn, 1992), an office (Donn 1993), a museum (Donn and Frost, 1992a), an art gallery (Donn and Frost, 1992b), and a police station (Donn, Fleming, et al 1993). In particular, it will concentrate on the questions that designers wish to ask and the type of answer they seek.

From the theoretical viewpoint, we examine the structure needed to provide a simulation platform that is truly usable by the designer. This problem is broken into two components. The first part of the problem is the definition of the structures necessary to create an integrated system of simulation tools (Amor et al. 1990). We develop the idea of a common building model which captures the information requirements of a range of simulation tools as the central component of an integrated system. We describe how a variety of simulation tools can exchange common data through such a common building model, eliminating the duplication of data when simulating a building in various design tools, and giving a single consistent model of the building at any one time.

The second major component of the simulation platform is a mechanism for providing views of the common building model to the various users of the system. This mechanism is likely to become a vital component of many developing systems with the introduction of the STEP standard for the exchange of product model data in the building and construction industry. While this standard will provide a model for the information requirements of the products used in the industry, it will require tailored user interfaces to present the data required by a particular group of professionals.

To tackle this second problem we propose a system that allows user defined interfaces to be described (Amor et al. 1992). These interfaces will provide a mapping of the data in the common building model to a form which is understandable to a user from a given profession, presenting the information in a language they understand and at a level of detail with which they feel comfortable. This system will also allow the user to tailor the interface

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to their own personal preferences, given their comprehension of various disciplines, and the information they feel is relevant to their work.

The Application of Simulation during Design

The mathematical simulation of energy flows in buildings can range from the one-time calculation of the energy balance in the reflection transmission and absorption of light, through the estimation of the dynamics of the absorption, storage, radiation, convection and conduction of heat, to the exchange of mass and heat energy by air movement. In each case, there is a minimum required amount of input data required to

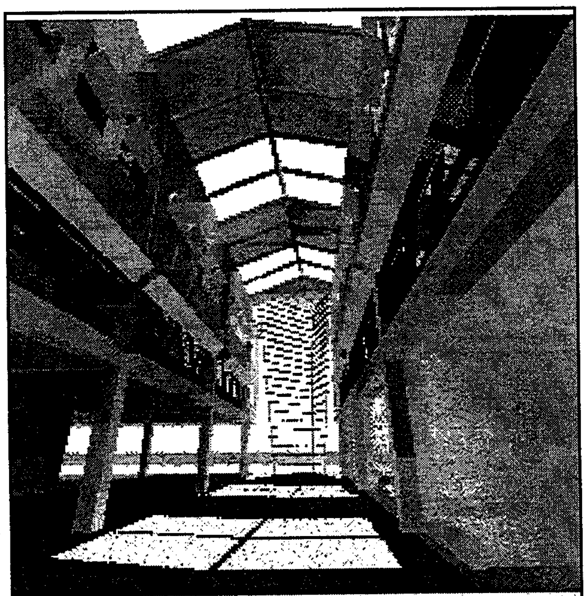

Figure 1 Computer generated picture of atrium in a university building

describe the physics. More critical to the eventual adoption of simulation as a routine tool in architectural design, are the need for principles of simulation design which address simplicity of data entry and the demystification of the results. In the following case studies, some aspects of these principles are illustrated.

The most difficult issue facing the writer of the computer based simulation program is deciding what questions the program is designed to "answer". At present, many programs are designed to produce accurate physical representations of the performance of the building. For example, the physics of the radiation exchange in a lighting environment can be modelled in such a way that the computer can produce an output which is a picture showing what the building might look like (Figure 1) given particular light sources. The designer in this case wants a mixture of quantitative information (light levels in lux to compare with the specification for the job) and the qualitative information in the picture.

Often the qualitative information will be most helpful if it can also be made quantitative. For example, in a recent exercise examining the use of daylighting in a refurbishment of a building as an art gallery, it was found that daylight factor contours and numeric values of illuminance were unhelpful to the client and the designer. What did prove of assistance, was the introduction of a single spotlight illuminating a surface in the gallery to 150 lux. This gave the pictures produced for varying external light conditions their own internal scale. (Figure 2).

Similarly, in an exercise examining the energy performance of a public library, the principal concern of the librarian was the potential for overheating. It was not enough to present data showing that for the TRY year of the simulation the maximum temperature was acceptably low. What was required was an analysis of the frequency of occurrence of the high internal temperatures. In fact, for the level of confidence that this client sought, with a natural ventilation cooling system, what was really

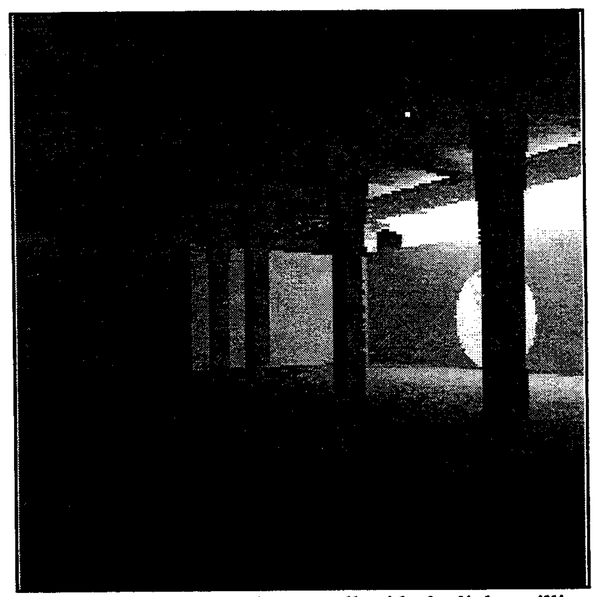

Figure 2 Spotlight circle on wall with daylight spilling over screen walls

required was an analysis of the likelihood of high external temperatures occurring without the local sea breezes. Only when armed with an analysis of the frequency of occurrence of high temperatures based on multi-year weather data, and with the coincidence data for high temperatures and wind, was it possible to answer the concerns of the client.

For yet another case, the client was planning a major museum development. Having elected to bring sun and day light into the major public circulation areas they were concerned to check the amount of light likely to spill into adjacent galleries. Naturally, in museums the

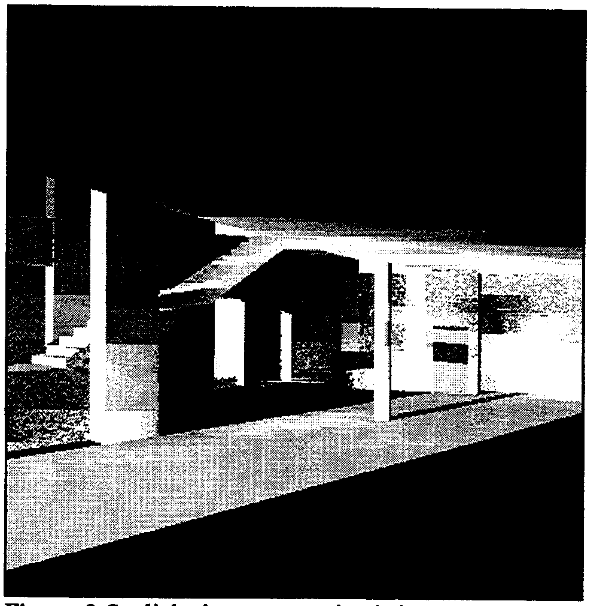
Figure 3 Sunlight in museum circulation zone

duration as well as the intensity of exposure to light is important as it can destroy some organic exhibits rapidly. Again, while the pictures from a ray-trace program were convincing as to the likely light intensities and the depth of penetration at particular times, nothing short of an animation could have shown the client how brief or long some exposures might be. For example: A particular south east facing window had sun shine to the back of the room behind it at sunrise; however, not only was the sun out of the space within two hours, but the exposure was only for a very few months in mid-summer (Figure 3).

In an office and studio development for a university, thermal and sunlight modelling was used to examine the likely performance of a central atrium/light well. In a four storey building of floor plan 3500 m^2, a 40 m^2 atrium can contribute significantly. In this case, while the ray-traced pictures provided some credibility to the analysis, and the graphs of internal temperatures some reassurance that the analysis was rigorous, the architects sought reassurance mostly about the degree of change likely in the analysis with variations in the design. As with all simulations of some rigour, each evaluation had taken a considerable time. Therefore, it was not possible to perform many simulations of a building this size and to provide a rigorous sensitivity analysis. What was most needed was the accumulated experience of a simulationist, familiar with the program and familiar with the type of simulation being done. Any analysis produced by a "black box" like a computer simulation program, must be able to assist the lesser experienced simulationist with interpretation of the results. Such sensitivity questions are at the heart of designers' decision making.

In the final case study, a regional police station of some 4000 m^2 was examined for its potential as a low energy building. Daylighting, natural ventilation and passive solar space heating were investigated. With the amount of equipment in the building, and with the high concern for security, many of the features which might have been attempted were abandoned. Here the biggest problem was developing a system of modelling at an appropriate level of detail such that the answers produced at the start of the design process were produced quickly and in multiple sessions while still enabling the modelling to develop to the much higher level of complexity required later in the design process. Often with the simulation programs available today it is easier to begin a new model than to develop a more sophisticated one on the basis of the old one.

In each of the above cases the essential requirement is for an expert sitting at the shoulder of the person using the simulation program. This expert has many roles to play. First they must remember the data from the lighting simulation so that it is available and consistent with the data entry requirements of the heating energy simulation. Second they must keep a record of the level of sophistication of the building model at each stage of the design process and maintain consistency between "versions". Third, they must provide advice and even analysis on the interpretation of the many thousands of lines of data that the program can produce.

An Integrated Environment

Many of the problems raised above appear to be met by a system which can allow a number of simulation tools to work in an integrated manner. Such a system would allow a designer to ask questions from various areas covered by simulation tools and provide some cogent method of obtaining answers. This was the reasoning behind the development of ICAtect (Intelligent Computer-aided Architectural design assistant) which was created to assist designers in the preliminary design phase.

ICAtect (Amor et al 1990) is structured into three main parts: the common building model (CBM); the tool interface; and the user interface (see Figure 4). The common building model was designed to incorporate the information required by a set of simulation tools used at the School of Architecture, mainly thermal and lighting tools, though structural and CAD tools were also considered. The common building model is an amalgamation of the objects, relationships and attributes found in these various design tools, integrated through data analysis of a similar nature to that employed in database schema integration (Batini et al 1986).

To enable the information in the common building model to be used by the design tools, and to garner the results of the design tools analysis, a mechanism for mapping data between models was necessary. This mechanism is provided by forcing the mapping of information between the tools and the CBM to be performed in two steps. One step is moving the information between the data files used by the tools and an internal representation of the tools building model. This internal model describes the structure of the objects in the design tools model, the attributes, their defaults, ranges, constraints on values, etc. The other step is manipulating the data between the CBM and the internal tool model, this step is concerned with the mapping of data between alternate data structures, performing unit conversions and range and constraint checking as the data is mapped between models.

The user interface is designed in a similar manner to the mapping provided to one design tool, except that the user is dealing directly with the model of the CBM. This means the user has a single interface to all the design tools attached to the ICAtect system, and needs only learn one language to use the integrated design tools.

At this point the ICAtect system is very similar to other integrated systems being developed in the research community. For example the COMBINE project (Augenbroe 1992) is an EC initiative which is seen as a first step towards the development of intelligent integrated building design systems'. COMBINE is structured in a very similar manner to ICAtect but covers a larger scope of the building industry in its building model, though ICAtect is different in that it is structured for preliminary architectural design. To support this stage of design it includes many defaults about properties of the building based on the building type. This means that the user has only to enter a very minimal amount of

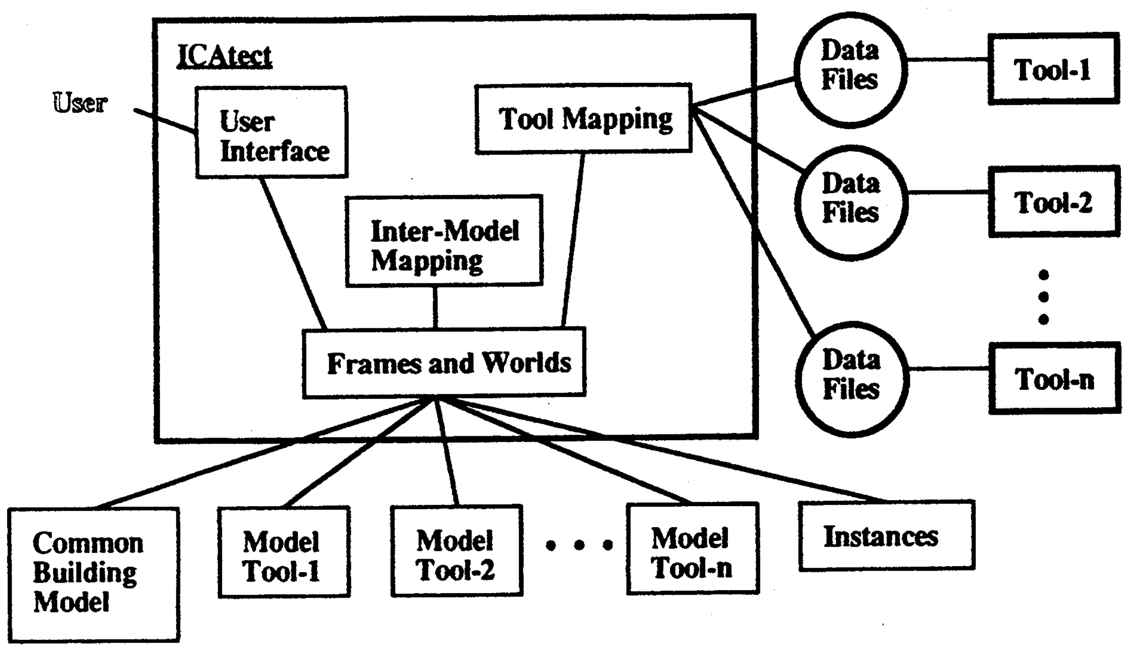

Figure 4 The structure of ICAtect

information before an analysis may be performed. In a similar fashion the AEDOT project (Brambley and Bailey 1991) is a USA led initiative which is examining integration in the scope of energy analysis tools. The work of Bjork et al and the STEP standard (STEP 1991) is interrelated with COMBINE and AEDOT and are approaching various aspects of the integration question.

One of the problems with these integrated systems is the user view provided to the base model. While most of these projects are studious in applying good user interface techniques to provide a friendly environment for the user to work in, the user must deal with objects and concepts which have been created to fulfil the requirements of various design tools rather than those with which they might actually conceptualise the object during their own design and work.

Views for Designers

As an introduction to this section it is useful to define a little more rigorously what we mean by a view of a base model. A view is defined to be the model of the objects and information a user has in mind when considering a given domain. In the case of an architect the definition includes the objects, relationships between objects and the information about those objects that a given architect perceives when they discuss a building. We are happy if this model is totally different from the base model in the computer, both structurally, in terms of the objects and relationships between them, and in the information content of any of the objects. What the definition is aimed at doing, given any users personal model of a building, and any given base computer model of a building, is describe and manage the mapping of information between these two views. When this system is developed it will allow users to converse with a computer based system at a level with which they feel comfortable, dealing with concepts they understand, and allowing the user to follow their particular methods of design.

There are already established methods for providing views to various models in some computer science disciplines, such as database systems and more recently in programming environments and constraint based systems. However, these view mechanisms make many assumptions about what can be translated between views, and how this translation is managed. The database views allow complicated views of the data to be displayed to the user, but only allow the user to add information to views which have a one-to-one mapping back to the base database model. In a similar fashion views in programming environments and constraint based systems, they may allow the user to see different structures in views through the use of functional dependencies, but the types of views that can be constructed and the methods available to construct these views limit the amount of flexibility of their view mechanisms.

As a first step to defining a method for defining user views several models of views have been created of a building derived from users in the industry and also from some design tools. For each of these views a mapping of the information between that view and the base building model has been created. Taking these mappings the types of information transfer that occur have been created, producing a set of mappings similar to those described in the database schema integration field (Kim and Seo 1991). This has highlighted the types of mapping that have to be accommodated to provide user views, and has thrown up some mappings which do not appear in the set of mappings considered in database schema integration. A list of some of the more difficult mappings encountered is shown in Figure 5.

Type	Meaning
OHOM	Objects have the same name but a different meaning in the models
OIMP	Object has implied attributes
OAFF	Object has an implied affect on the rest of the model
ODIF	Objects have different names in the models and are different but contribute to each other
ACON	Attributes have different constraint checks in the different models
AFUN	There is a functional dependency between attributes

Figure 5. Mappings between models.

As a first step to providing a system that can handle user views with mappings as in Figure 5 these models have been implemented in the object-oriented visual programming environment MViews (Grundy and Hosking 1992). This system is structured to allow multiple overlapping views of an object-oriented programming environment to be displayed and manipulated by the user. The system provides a lot of the power needed to provide user views through its support of multiple textual and graphical views of an object with automatic consistency management between changes in any of the views (see Figure 6 for the CBM in the MViews environment).

The second step to providing user views is to expand the mappings supported in the current MViews system to handle the variety of mappings which were found in the mappings between the CBM and the various user and design tool models of a building. Initially this is being approached by writing the code required to perform all the necessary mappings between the various views and the CBM. When all these mappings are defined the commonalities between the various mappings willl be extracted and a start made on defining a system which allows the user to describe mappings of these types which will automatically make use of the pre-defined mappings.

Conclusions

This paper details the need for an integrated simulation environment for the early design phase. We describe the

ICAtect system which provides a methodology for creating an integrated simulation environment which supports the early design phase. This system is created by providing a common building model which represents the information requirements of a set of design tools, and then providing a system to allow the mapping of information from this model back and forth between the various design tools. While this provides a system which allows the user to converse with one model to use several design tools it must be further extended to provide a mechanism for describing multiple user views which can be mapped through to the common building model. This gives the user an interface which is truly personalised to represent their model of a building.

Acknowledgment

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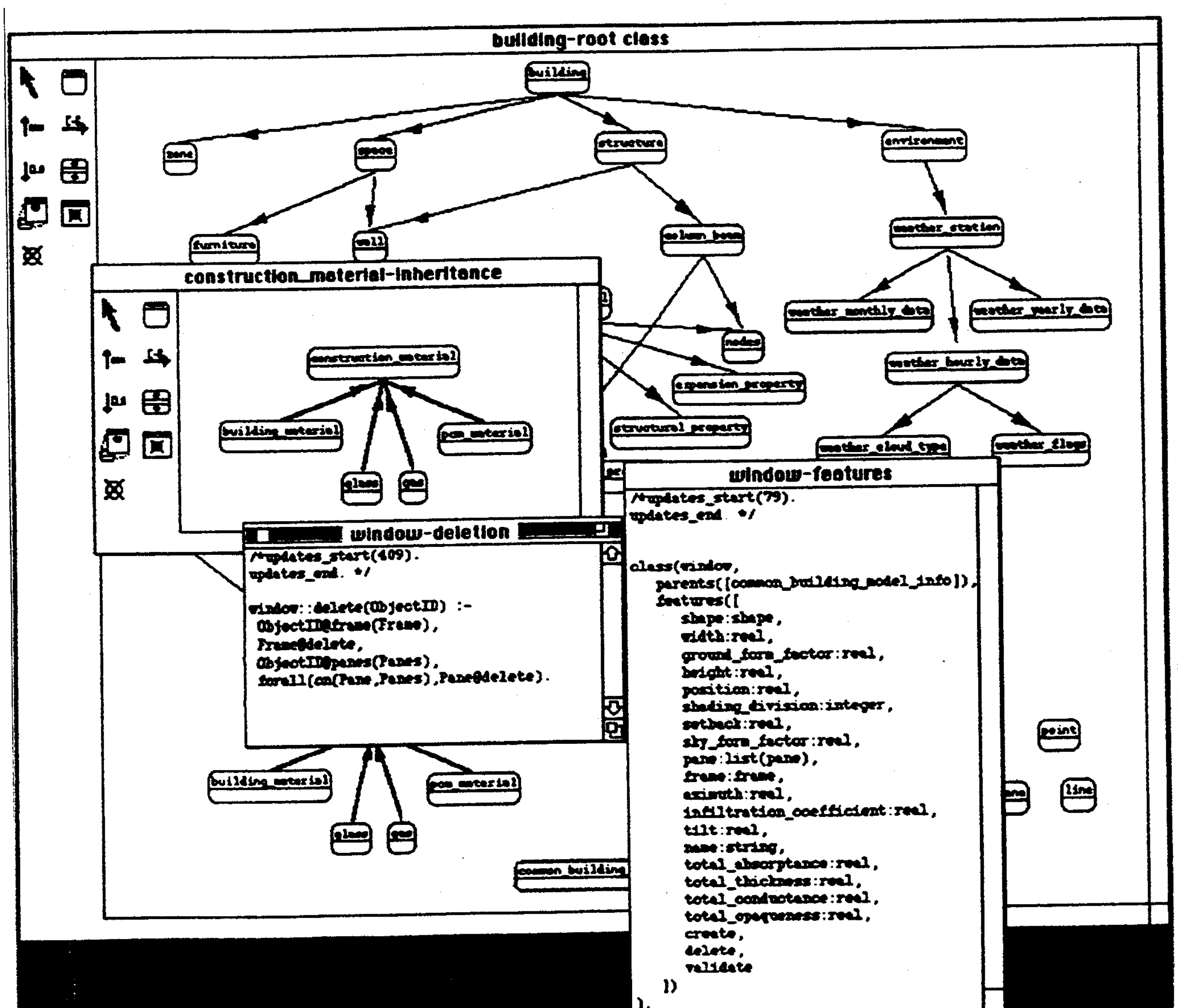

Figure 6 The Common Building Model in Mview

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