STEPHANIE: A Simplified Approach To Energy Analysis in Buildings

DIONÍSIO, J. M. S.*
ZGDV - Zentrum für Graphische Datenverarbeitung
Computer Graphics Centre
Darmstadt, Germany

ABSTRACT

This paper addresses the development of a prototype system for energy building simulation by coupling commercially available CAD systems for architecture to numerical computational methods. Three fundamental directions of the research work are presented:

- *enhance and expedite the traditional and manual design activities;*
- *open new design possibilities in building design by exploring graphics, database capabilities and innovate programming;*
- *interfaces to generally available computational software using the same graphical environment. Highlights are the relevance of emerging CAD technologies and integration of disciplines within the building design domain using a common user-friendly interface. This will be exemplified by the design of a building floor plan. A procedural pipeline for the method is briefly described.*

INTRODUCTION

In today's competitive environment, the demands on architectural and engineering firms are increasing more than ever. Architects and engineers are asked to respond to increasingly complex and challenging design problems while adhering to aggressive project schedules. To remain competitive in this environment, computer-aided design (CAD) tools are used to speed the design and drafting process. However such enhanced flexibility and productivity tools, represent only the first step.

Personal experience and/or educated guesses are definitely not the right way to overcome limitations of experimental information.

Existing energy analysis algorithms also require excessive amounts of input in order to produce exact predictions.

Designers complain about the scarcity of well suited tools and simulation loops become hard to perform. Therefore proposed design plants are often oversized. Oversising, besides being a penalty on the investment cost usually translates also, in higher energy running and pollution costs due to bad performance. These waste of precious resources, which had been in a recent past favoured by two decades of low energy costs, is no longer compatible with design methodologies offered by present computer technology and software tools.

A desired solution would be one that incorporates input from architects, engineers and builders as well. A flexible system capable of handling both graphic and non-graphic information with ease and offer the users the power of fast and easy interactive simulation (Eastman 1989).

With this scenario one can conclude that much can be done even using existing models and algorithms

* Wilhelminenstr. 7
D - 64283 Darmstadt
Fax : + 49 - 6151 - 155199
E-Mail : dionisio@igd.fhg.de

if new techniques are developed to improve man-machine interface (Clarke 1989).

STEPHANIE is presented as a simplified approach to energy analysis in buildings because it relies only on a few number of mechanisms to ensure that the performance characteristics of a building will be acceptable. Focused on the early stages of design where different architectural layout alternatives are tested, predominantly architects domain, simple calculations are applied with a minimum extra non-geometrical data input. A large set of tools are provided to manipulate architectural entities and their attributes rather than the development of an high accurate energy algorithm towards an optimised plant or, e.g., control air movement (only needed on further advanced stages of detail).

The idea is mainly the use of a CAD environment as a working platform and the definition of a building product model capable to be used by architects on early stages of design allowing future engineering refined analysis. As known, in this stages more than an accurate value which depend on a lot of data entry usually not available, an approximate value is capable to give immediately an idea of involved peak loads and automatically alert to possible solutions depending on geometry or attributes given.

Nothing better than a CAD environment to manipulate easily and interactively this geometrical entities, its attached attributes and, automatically produce a new (set of) output format file(s) ready to be used as input data by complex but accurate computational algorithms (e.g. ESP).

To achieve this goal an integrated database structure that supports CAD geometric data and external attributes (non-geometrical) related within the building was defined. Besides reducing the amount of multiple data handling that would otherwise be performed by each user, this integration provides a higher level of data protection from human error as well.

STEPHANIE will be described as a pipeline comprising four modules: architectural geometric modelling, building attribute specification, simple energy evaluator and visualization (Fig. 1).

MODEL DESCRIPTION

As mentioned above, the system integrates four independent modules. It follows a brief overview over each one.

Architecture layout manipulation:

distinct input data CAD formats are accepted and converted to an internal format. Geometrical primitives as well as previously defined elements are stored and available from graphical libraries

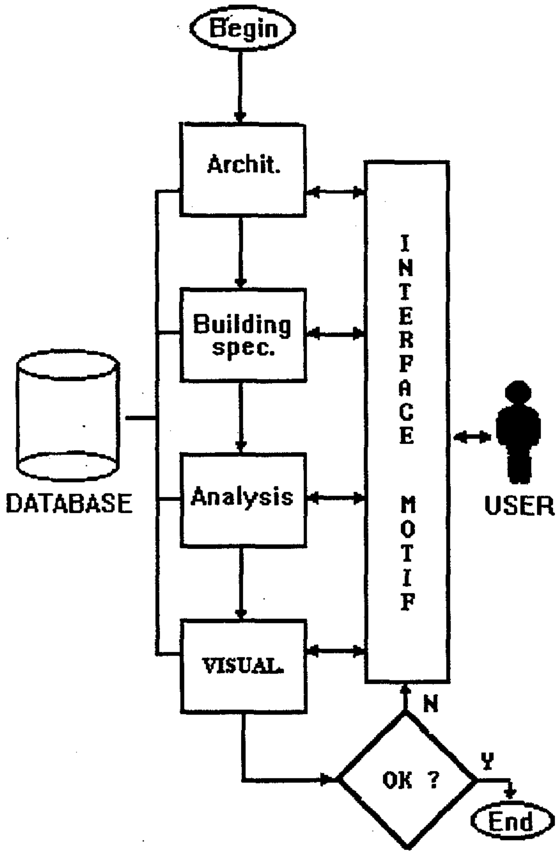

Fig. 1 Simulation pipeline of STEPHANIE

Attribute dialogue facilities:

prototype entities (e.g. surfaces, fenestration) are defined in several databases. These elements, hierarchically linked, provide the required knowledge about the building(s) structure to the system. Primitive componentsare building, floor, room, surface and fenestration. Geographic, climate, and material's thermal data are also available and default values can be used on demand

Thermal analysis:

a numerical module reads data from databases and provides several interface options to third-party calculation programs. It also includes a quick analysis mode (own evaluator) to get fast feedback about partial (space loads) and overall load of the entire building (on-line simulation)

Visualization dialogue facilities:

collection of graphical functions capable to

- present graphically the input data (e.g. temporal variation of design parameters)
- visualize the building envelope and/or interior layout
- navigate and dynamically visualize the obtained results
- interface to previously defined graphical libraries (e.g. furniture, equipment)
- display rendered images including images from third-party applications (e.g. TIF, RGB formats)

SIMULATION

Only through the efficient use of energy in each building (brand new or existing ones) will be possible to reduce energy consumption to acceptable levels. For this, engineers and architects require "suitable" design procedures and software tools to achieve optimised levels of energy consumption. One way to achieve this goal is *Simulation* (Clarke 1985).

A user-friendly interface between the mentioned design tools was developed (Fig. 2) enabling specification and access to design parameters and element's structure (specification attributes, e.g., layers, codes). Work is progressing to improve this interface and proportionate the power of simulation among distinct related design disciplines (Dionísio 1992b).

The product model is entered attaching geometrical elements from the design file with available database prototype records called prototype entities. Each prototype record embodies a set of attributes defining an architectural entity of the real world (interior wall, exterior door, and so on). Besides geometrical attributes (automatically entered when attaching) and non-geometrical attributes (materials, layers, etc.), each element has a link to its "parent". This way, instead amalgams of entity occurrences is also defined an hierarchy between elements. This hierarchy is defined through several links between fields in each entity structure allowing inheritance and avoiding redundant or duplicate information.

Prototype entities are available from the interface's main menu and become active by users' choice in a catalogue format. Parallel to this process, distinct data as materials, surfaces, codes, weather data, and so forth, are available and can be configured since it is independent from components (entities) of the building.

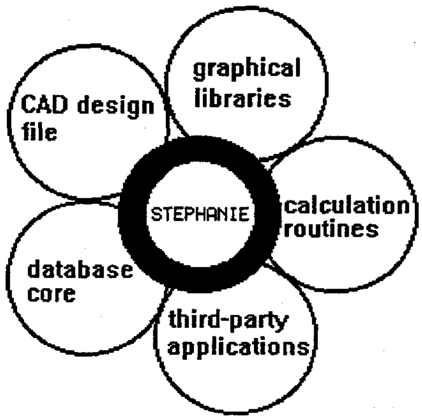

Fig. 2 Conceptual interface modules

Our prototype leads to a supported database model which accepts data from the CAD module and the graphical user interface, and integrates and pass data to the calculation and visualization modules [Sreekant et al.85].

Fast specification of all the needed parameters is provided by a large set of default values which are displayed on the active dialogue boxes. Default values can be updated when needed.

Once all the relevant information is stored in the database core, different third-party applications may be called through the same interface. Each interface routine checks if there is enough stored data to perform the desired calculations and, on case, offers the user the possibility to insert the missing data. Interface routines read database files and write ASCII files which have the required sequence of commands and are used as input data to the chosen solver which may run on other machines (batch evaluation). A future topic of development could be the interpretation of the results from this third-party evaluation application and its reintegration within the simulation pipeline give the user the possibility to activate the available visualization facilities and redesign his original model (Fig. 3).

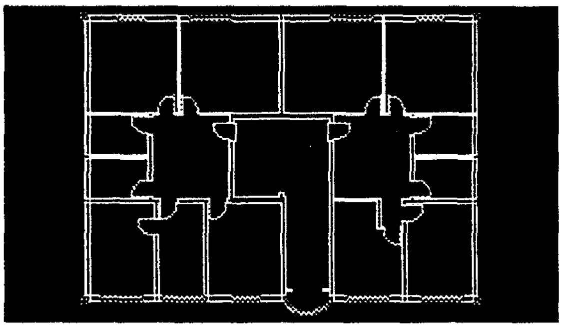

Fig. 3 Demonstration layout

Graphical output enables users to check whether generated colour coded outputs fulfil the application's requirements and cycle through the simulation pipeline. Modifications may be done on-the-fly (Fig. 4, Fig. 5).

Requirements are met in terms of type of room (e.g., office, computer room) and correspondent heat loads. Colours (green, yellow, red) define degrees of acceptance, tolerance or even rejection.

As an example take an heat load whose range should lay between 100 and 120 W/m2 with a tolerance of 20 W/m2. A computed value of 110 W/m2 will be represented as green, whereas a value of 130 will be displayed as yellow (it is within the tolerance range) and 145 as red because it is beyond the tolerance range.

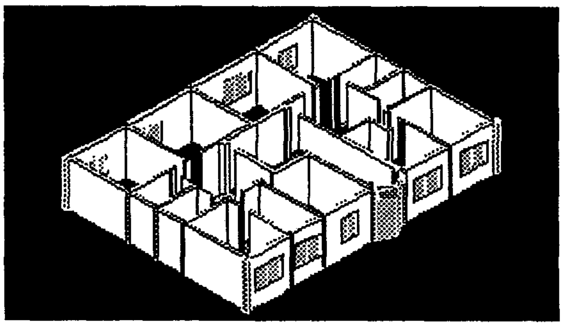

Fig. 4 3D rendered layout

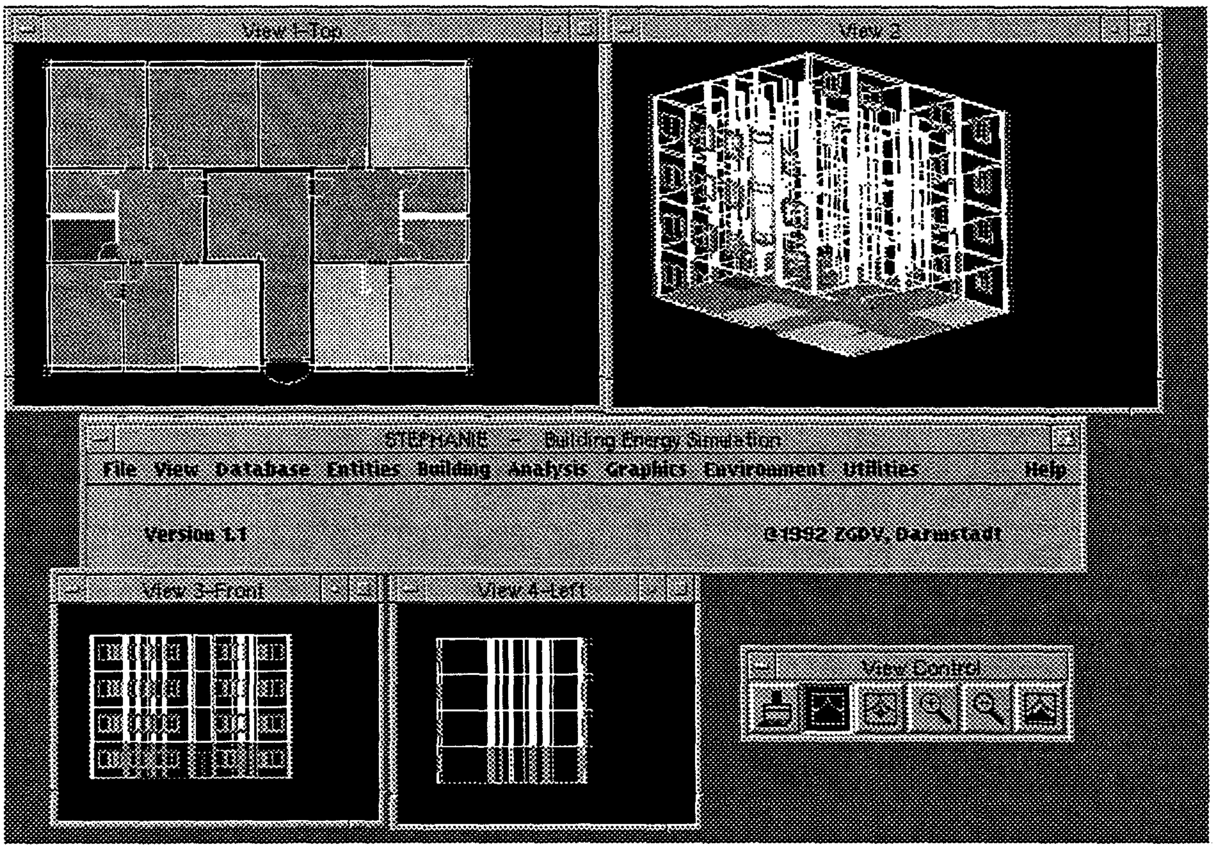

Fig. 5 Aspect of thermal simulation

There is no doubt that visual communication between external media and the designer is fundamental in the design process. Thus, it is our purpose that a system like this with virtually unlimited access to graphics, along with analysis and reporting tools, provides effectively handling of all the information related to buildings (Dionísio 1993).

DISCUSSION

G. Schmitt (Schmitt88) wrote "Although there is no guarantee that a combination of circumstances and sophisticated tools will result in creative design, they can improve the probability of creativity on a rational basis. It is difficult to predict what impact the availability of a powerful microcomputer would have on the creativity of Leonardo da Vinci, Michelangelo, or Einstein. It is safe to assume that a good computerised visualisation tool will reduce the feedback time between the development of an idea, its representation on an external medium, and its realisation. Thus, a larger number of variations can be observed and invalid solutions can be discarded quickly."

Although major barriers will always remain mainly because of shortcomings with user interaction, ease of communication is a crucial element. From the user point of view, data should be accessible at any time, easy to understand and different levels of detail should be provided. On the other hand, not only architects and engineers should be provided with communication lines between themselves, they also should have the possibility to supply project information for internal checking or to accreditation officers.

Any solution will always be a compromise between the need for a powerful model, which is understandable and rigorous and, on the other hand, simple, effective and intuitive in order to ease interaction. However, besides a good computerised visualization tool, a set of other main clauses were taken into account, as follows:

- several levels of simulation as the project runs on

- the importance of "the first value" instead of "the correct value" (the valuable help of default values)

- easy-to-use, fast-running and well documented computer program

- regulations and by-laws

- reports and schedules that could be extracted from individual sets of elements

- interface to distinct algorithms and third-party applications (either calculation or visualization)

CONCLUDING REMARKS

The results of STEPHANIE are in no way revolutionary on building simulation, since the mathematical concepts or the underlying formalism in each independent module have been a research topic and a quite number of prototypes exist (Björk 1989, Pan et al. 1991). However, the integration of the given facilities within the graphical user interface through the simulation pipeline provides the user with minimum user input, for the rapid exploration of alternative decision-making.

STEPHANIE concepts are also extended to support several third-party energy analysers (ESP is intended to be included in the near future) including its own evaluator. The database core and the default values reduce the time necessary to data input and increase accuracy. Graphical interaction and simulation tools enable the user to easily control different levels of design and detail. Within this abstraction it is always possible to develop future routines to interface with new energy applications.

We believe that our system embodies a set of facilities capable to integrate these concepts. As M. Metcalfe (Metcalfe69) said: "...sophistication is a luxury; good working conditions are essential; high living conditions are desirable; but good building and fine architecture has only come about when the architect and the team of engineering experts in all fields have stretched themselves to the limits of their ability." Therefore any attempt to decrease the existing gap between different teams is valuable and welcome.

A prototype is being developed in the C programming language and runs under DOS and UNIX operating systems (MicroStation 1992).

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