IMAGE: A simulation-based tool for the appraisal of advanced glazing

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ABSTRACT

The IMAGE (IMplementation of Advanced Glazing in Europe) project was funded by the European Commission and involved glass manufactures, consultants and research organisations (see acknowledgements). The aims were to encourage appropriate applications of advanced glazings, to raise awareness of existing products amongst designers and to improve building simulation in relation to combined thermal and lighting appraisal [IMA1998].

A principal outcome of the project was the release of a PC application – hereinafter termed the IMAGE tool - for use by the glass industry to assess the impact on energy use, thermal comfort, daylight availability, glare, etc. of applying any advanced glazing component to any building type in any climate.

The IMAGE tool comprises a user interface, which gives access to databases of building types, glazing components and climates. This interface supports the rapid composition of building/glazing/climate combinations and controls the commissioning of fully dynamic thermal/lighting simulations.

This paper describes the principles inherent in the design of the IMAGE tool, the adaptations made to the ESP-r system to support automatic multivariate performance assessment, and the protocols developed to manipulate building models, glazing components, climates and performance appraisal returns.

INTRODUCTION

By placing an intuitive PC interface in front of a powerful contemporary simulator and limiting the domain of applicability, the intention is to help neophyte simulation users to perform advanced building appraisals. As explain in [MOR1995], the advantage of this approach is that it minimises the input burden placed on the user .

The aims of the program are:

1. To provide a simplified interface to ESP-r [CLA1996] that allows a simulation of a selected building, glazing system and climate. This interface was designed for use by R&D personnel working within the glazing industry. On selecting a building, a glazing system and a climate, the user obtains performance indicators for energy, pollution, visual and thermal comfort.
2. To allow glass manufacturers to quantify the overall performance (energy, comfort, etc.) of a building when placed in a given climate and with alternative glazing systems applied [CLA1998]. The IMAGE tool allows the definition of parameter permutations via simple selections from lists of named entities.
3. To display simulation results of pre-calculated permutations recovered from a database. This feature was developed for use by marketing people: on selecting a building, a glazing system and a climate, the user obtains immediate feed-back on the overall performance impact.
4. To import glazing files from external programs such as the WIS [WIS1996] and WINDOW 4 [WIN1994] systems which are widely used for glazing system evaluation.

The key point is that, for the first time, both company branches - marketing and R&D - can gain access to the power of integrated performance simulation though a purpose-specific interface.

METHODOLOGY

The tool is able to both extract pre-computed results for standard cases and commission simulations as required. This first capability provides rapid access to comparative data in support of apt glazing component selection. The second capability supports investigations into new product performance and atypical building/ climate/ product combinations.

In both cases, a combination of a building, a glazing system and a climate are selected by the user. As depicted in Figure 1, the difference between the marketing and R&D versions of the tool lies in the lists of entities available for selection. In marketing mode the lists contain only buildings, climates and glazing product combinations that have previously been simulated and performance details stored. In R&D mode, the lists contain all buildings, climates and glazing products known to the tool.

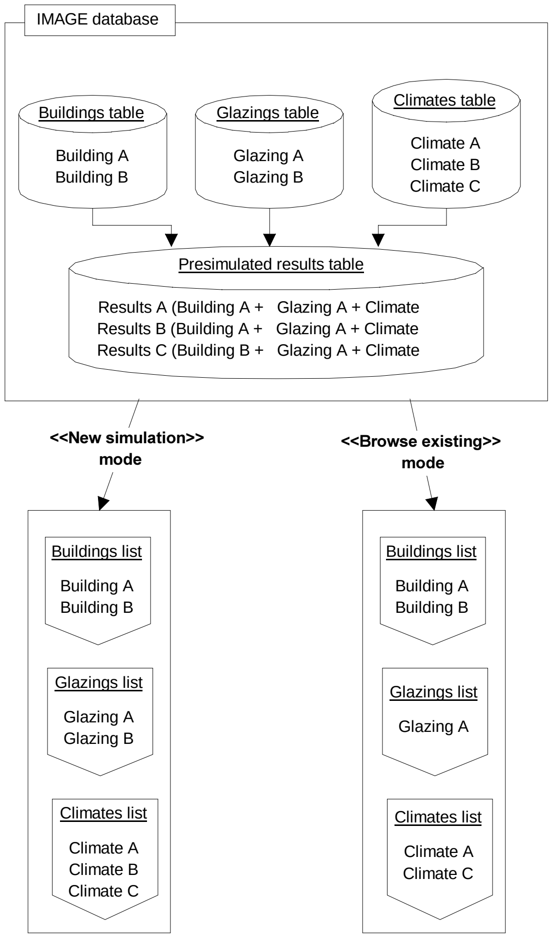

Figure 1 *Browse existing* & *New simulation* modes.

The IMAGE database contains four tables: the first three contain information on the buildings, glazing systems and climates. The fourth contains results of simulations that have already been performed.

Browse existing

To navigate existing simulations, a combination of a building, a glazing system and a climate is firstly defined. In this case, the lists only display items that correspond to a recorded simulation result.

Each time an item is selected from a list, the interface automatically updates the other lists to prevent the selection of a combination that has not previously been simulated. Figure 2 summarises the process of combination definition and result display.

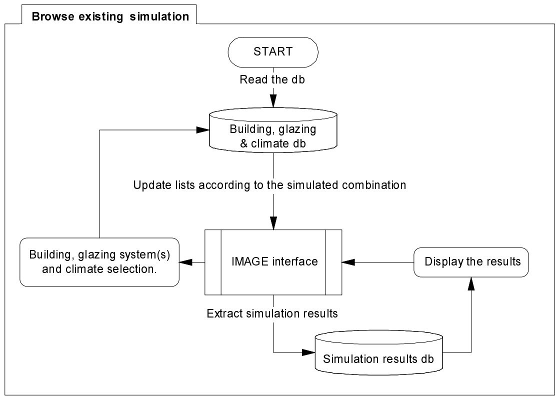

Figure 2 Browsing through existing simulations.

New simulation

To run a new simulation, a combination of a building, glazing system and climate is defined. For each category the user is offered an unconstrained choice so that any combination of building, glazing component and climate is possible. Figure 3 summarises the process.

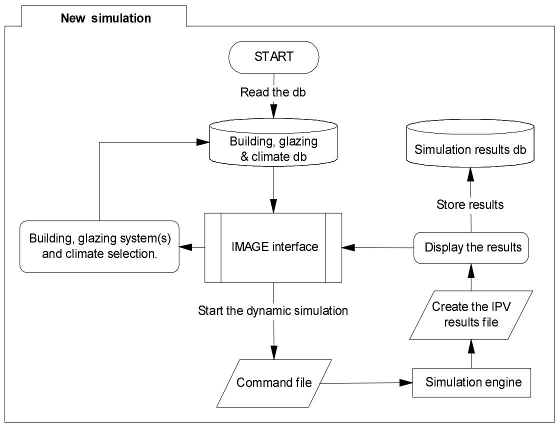

Figure 3 Commissioning a new simulation.

When the (automated) simulation has been completed, the results can be stored within the IMAGE tool's database for future recall in «Browse existing » mode.

IMAGE PROGRAM INPUT

To reduce and simplify the interface, the user input is limited to a selection of a building, a glazing system and a climate.

Building

When a building name is selected in the list, related information such as location, glazing area, volume, etc. are displayed as shown in Figure 4.

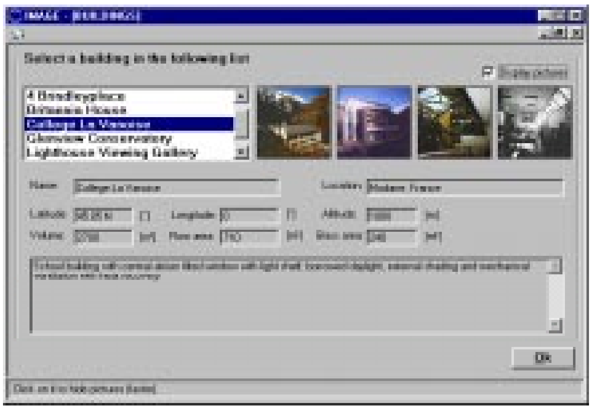

Figure 4 Building information feed-back.

Pictures or sketches are also displayed with enlargements possible to help with clarity.

Glazing system

Glazing systems are defined in terms of their global and angular properties in order to support highly resolved simulations as required by the glass manufacturers.

As shown in Figure 5, the interface is able to display all standard glazing system parameters, such as global visible, solar and thermal transmittance.

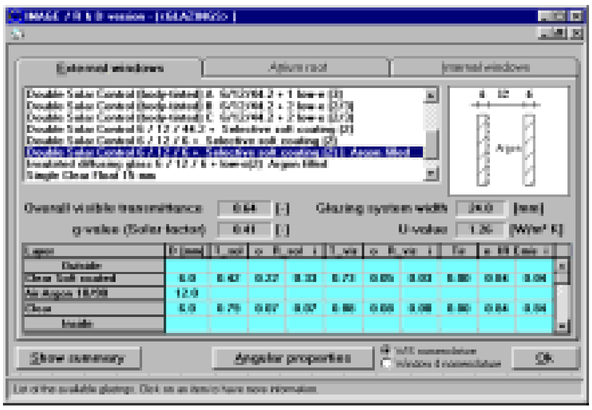

Figure 5 Information and pictures related to a selected glazing component.

Because the glass manufacturers are concerned with the detailed performance, the interface also displays angular values for

- global visible transmittance;
- global visible reflectance (inward and outward);
- global solar transmittance;
- global solar reflectance (inward and outward);
- pane solar absorptance.

The location of glazing systems depends on the selected building. A flexible application protocol has been enabled in ESP-r by which glazing components may be automatically applied to external facades, atria roofs and internal partitions (Figure 6).

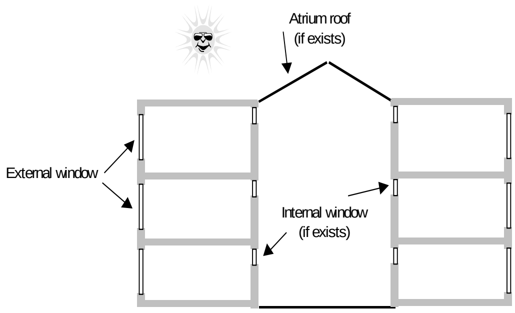

Figure 6 Supported glazing locations.

Each location can have a different glazing component applied. This flexibility allows the program to represent a wild range of building shapes from a simple house with a conservatory to a complex office building with an atrium.

Climate

To support dynamic simulations, the following hourly climate parameters are held within the tool's database:

- horizontal diffuse solar radiation;
- direct normal solar radiation;
- dry bulb temperature;
- wind speed;
- wind direction;
- relative humidity.

As shown in Figure 7, the IMAGE tool interface offers the possibility of displaying all of these parameters jointly and severally.

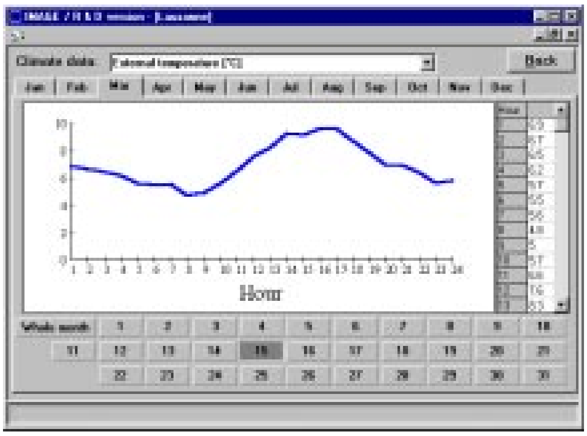

Figure 7 Climate data display.

Furthermore, facilities have been developed to add new buildings, climates and glazing components to the IMAGE database. It should be noted that the tool has no on-line facility to create a building model. To import a new building, a model must firstly be made using the facilities of ESP-r.

SIMULATION ENGINE

The project manager, simulation and results analysis modules of ESP-r have been implemented under Windows NT with adaptations to enable the IMAGE tool interface to automate the processes of problem generation, simulation and multivariate performance index extraction.

When a simulation is requested by the IMAGE interface, a command file is sent to the simulation engine as shown in Figure 3. This file contains the following information as required to support the simulation:

- ESP-r problem identifier;
- building identifier;
- glazing type and location identifiers;
- climate identifier;
- simulation parameters.

This command file is read by ESP-r's project manager which automatically attached the selected glazing components to the given locations. When this task has been completed, a simulation is started in background mode. Taking advantage of the multi-tasking feature of Windows NT, the IMAGE program allows the user to continue using the tool while the simulation is running.

When the simulation is completed, the results analysis module is invoked (gain in background mode) to create a pictorial overview of the building's multi-variate performance state. This overview is termed an integrated performance view or IPV. The user is then able to display the IPV and, optionally, store it within the IMAGE database for later recall when operating in the marketing mode.

RESULTS

An IPV is a collection of relevant performance metrics which, together, define the buildings overall performance. At the present time these metrics include a mix of fuel use, comfort and environmental impact factors as follows:

- an image of the building;
- maximum heating, cooling and power demand;
- energy demand profiles by season;
- normalised energy requirements.
- related gaseous emissions taking account of power station fuel mix and plant efficiency;
- thermal comfort distribution;
- visual comfort and glare;
- daylight distribution;

The IMAGE tool has two facilities to handle these simulation results.

Firstly, it can group and display the above performance metrics into the standard IPV format as shown in Figure 8.

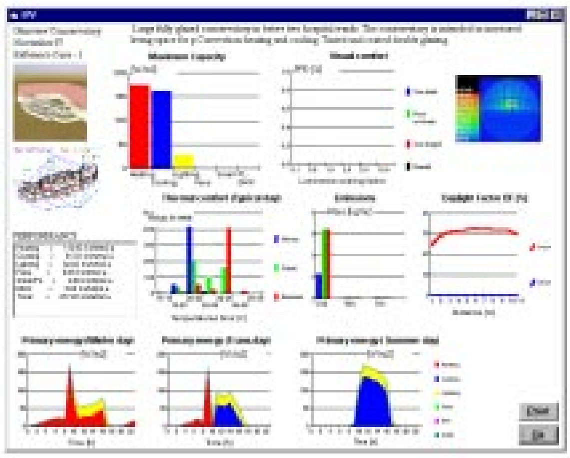

Figure 8 Integrated Performance View (IPV).

Secondly, it can display performance metrics from different simulation in side-by-side mode as shown in Figure 10. This facilitate the ready comparison of variants and supports an analysis of the impact of glazing types on specific performance categories in the context of specific building types and climates.

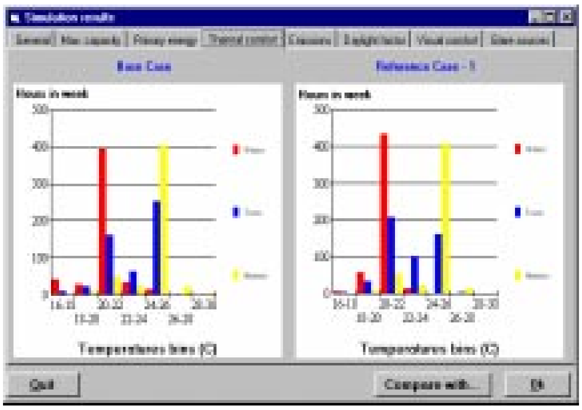

Figure 9 Variants comparison in the IMAGE tool.

CONCLUSIONS

The IMAGE project has produced a simplified computer-based tool that provides accurate results of complex simulations via a user-friendly interface. The tool is implemented on a PC under Windows NT.

This tool is intended to support glass industry personnel concerned with existing product marketing and new product R&D. The tool is composed of an interface (Visual Basic) connected to the ESP-r system and several databases with pre-loaded entities defining building models, glazing components, climate collection and, for some typical configurations, IPVs. Full importation of data from the WIS and WINDOW 4 programs is supported because these programs are widely used for glazing system characterisation.

In both modes of operation - *browse existing* and *new simulation* - the powerful IPV concept is used to convey the overall impact of specific combinations of buildings, climates and glazing products.

Because tool operation is simple, it can be used as an educational tool in order to increase student awareness of the impacts, positive and negative, of advanced glazing systems on building energy performance.

Planned future developments of the tool include support for building life cycle assessments (using the same approach as in [CIT1998]) where factors such as the energy embodied in constructional materials, and the re-use of these materials at the end of the building's life, are added to the factors already contained in the IPV as plant control or the wall composition, could be added.

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REFERENCES

[CIT1998] S. Citherlet and F. Di Guglielmo, Window and advanced glazing systems Ecobalance, Energy & buildings, to be published.

[CLA1996] J. A. Clarke, The ESP-r System: Advances in Simulation Modelling, Building Services Journal, May, pp. 27-9, 1996.

[CLA1998] J. A. Clarke and M. Janak, Assessing the overall performance of advanced glazing systems, Solar Energy, Vol.: 63(4), pp. 231-41, 1998.

[IMA1998] IMAGE Project Newsletters, available from HGa Ltd, Burderop Park, Swindon, Wiltshire SN4 0QD.

[WIS1996] Advanced Windows, Information System (WIS), ERG, Energy Research Group, University College Dublin, School of Architecture, Richview, Clonskeagh, IRL - Dublin 14, 1996.

[WIN1994] WINDOW 4.1, for Analysing Window Thermal Performances in Accordance with Standard NFRC Procedures, LBL, Windows and Daylighting Group, Laurence Berkley Laboratory, Berkley, CA 94720, 1994.

[MOR1995] N. Morel, S. Citherlet and A. Faist, BATMAN, A Computer Aided Learning Module for Architecture Students, European Conference on Energy Performance and Indoor Climate in Building, Lyon France, 24 to 26 November, 1995.