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DEVELOPMENT OF BASE EFFICIENCIES IN BUILDING ENVIRONMENT SIMULATION FOR BUILDING SIMULATION 2003 CONFERENCE

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ABSTRACT

A set of geometry translation tools and capabilities have been developed to increase base efficiencies in the simulation of both the internal and external environment of buildings. The tools allows us to build a 3D model in one package and then translate the geometry for use in a number of other simulation packages that we use.

Though not a unique concept, it does allow the use of preferred software for undertaking the building of the 3D model. This removes us from being restricted to one single integrated simulation package and any inherent limitations that such software may carry.

A 3D model developed by architects in a CAD package can also be translated and used for simulation purposes.

Major efficiencies in time are achieved in the real world from developing and using translation tools for simulation software.

A discussion is presented in the paper comparing and contrasting the performance of the tools developed to the International Alliance for Interoperability's (IAI) Industry Foundation Class (IFC) system for interoperability.

INTRODUCTION

The largest time consumer in undertaking building environment simulation is developing a sufficiently detailed 3D model. If simulation is being carried out on a large number of different aspects of a building, a lot of time is employed solely for preparing the geometric models prior to simulation.

Savings in time are achievable by making the model building process more efficient.

One way of achieving desirable increases in efficiency is to produce a fully integrated software package that contains a model builder along with all of the software that is required to conduct the different simulations. Unfortunately, this results in restrictions on what software tools you have at your disposal. More effective or more user-friendly tools may be available for conducting the same simulation.

Another way of achieving the desired efficiencies is by developing translation software that reads in one geometry file format and outputs the same model in another geometry file format.

This approach allows the end user to choose preferred software for undertaking simulation tasks. Flexibility and capability is greatly enhanced as a consequence.

CONCEPTUAL DESIGN – 'JUMP IN EARLY'

Due to efficiencies achieved by using translators, broad brush simulation can be conducted very early on in the conceptual stage of a buildings life. This is the best time in the design process for the building engineers to provide input.

The design and planning is still flexible enough at this stage so different options cen be quickly and efficiently assessed. Items such as:

- Mechanical ventilation
- Natural ventilation
- Daylighting
- Shading
- Fire and smoke movement
- Occupant evacuation and circilation

can all benefit from this 'jump in early' approach to the services design phase.

Architectural planning can be modified with little impact at this early stage. The architect can replan around any requirements identified from simulation at this point in the design process without causing a large impact on the building concept.

SUSTAINABLE DESIGN

By definition, the aim of making buildings more sustainable is to place less demand on the Earth's resources in the creation and use of those buildings.

The aim is therefore to design buildings which rely on a more 'natural' internal and external environment in functionally accomodating the people or processes they are required to do.

The fundamental conflict then arises as to the levels of expectation of 'comfort' which have been developed over the past 50 to 100 years by the provision of artificial environments in our buildings.

Acurate predictions of naturally treated (lit and ventilated) buildings has historically been a 'black art'. Therefore, the development of numerical tools to allow engineers to predict the effect of naturally treated buildings both accurately and cost-effectively at an early stage of development of the architectural concept much greatly enhance the cause of sustainable building design.

The ability to refine life safety systems in those buildings at little additional effort is an added bonus.

TRANSLATION SUITE

The translation suite has been developed to allow simulation of the following items from one 3D model.

1) Thermal analysis – HVAC, mixed mode ventilation, natural ventilation
2) Energy consumption
3) Daylighting
4) Artificial lighting
5) Fire growth and smoke movement
6) Evacuation and pedestrian circulation

Table 1 indicates in a simple form the main translation capabilities that have been developed and used.

FROM	TO				
AutoCAD	IES	Phoenics	STEPS	AutoVIS	FDS
IES	-	Phoenics	STEPS	AutoVIS	FDS
Phoenics	-	-	-	-	FDS
STEPS	IES	Phoenics	STEPS	AutoVIS	FDS
AutoVIS	IES	Phoenics	STEPS	AutoVIS	FDS
CFX	IES	Phoenics	STEPS	AutoVIS	FDS

Table 1
Translation capabilities.

The software packages listed in the table above are used for the following simulations. It is noted that these packages are not limited to the items listed below.

- IES – Thermal analysis, shading analysis, daylighting analysis
- Phoenics Computational Fluid Dynamics (CFD) – Fire growth and smoke movement, pollution and contaminant concentration, wind analysis, air movement and thermal performance
- STEPS – Occupant evacuation and circulation analysis
- AutoVIS – Lighting, daylighting and shading analysis
- FDS (Fire Dynamic Simulator CFD) – fire growth and smoke movement
- CFX (CFD) – as per Phoenics

EFFECTIVENESS

The effectiveness of translation tools is determined by their robustness. This means that a translation tool should produce an input file or geometry file for another software package that will open without glitch and be free of limitations.

Large efficiencies have been realised on a number of projects where the tools have been used. In one project 5 weeks of model building time was saved because the model used for wind, rain and fire modelling was seamlessly used in another package for daylighting, artificial lighting and shading analysis.

Once a high level of robustness has been achieved high levels of efficiencies are also achievable. One translation tool, that from IES to STEPS also generates default information on exit paths, exit locations, people groups and people types during the translation process. Blockages to occupant flow, room names and level information is all processed during the translation process.

By incorporating such information into the import process, many hours of post model building setup time can be reduced to seconds. This method of translation is more advanced then the typical translation process that we employ and is reflective of the religious goal being aimed at by the International Alliance for Interoperability's Industry Foundation Class system.

The IFC system aims to store all information for a building model as a common database that can be read by many different software packages.

TECHNICAL DIFFICULTIES IN DEVELOPING ROBUST TRANSLATION TOOLS

One common limitation that is was found during the development of the translation software is that different simulation packages read and write information for a model in different ways.
The development of the translation tools has to be well thought out prior to development so that the desired format is produced from the translation.

Some packages rely on all objects being drawn orthogonal to the x, y or z axis coordinate system. Other packages allow objects to be placed at any angle to the coordinate system. This can cause problems when translating from one to the other and a simplification has to be made to account for the reduction in information required by the second software package.

These limitations can be dealt with by simplifying the original model or by making the translation tools more sophisticated such that they interpret a component at an angle to the coordinate system and break it up into a series of components that are orthogonal to the coordinate system.

The translation tools developed are robust enough that a model can be translated to most other packages without requiring oversimplification of the original model. The translation to Phoenics and FDS may require the original model to be simplified if it is complex or has components that are not orthogonal. This can be incorporated into the original model building so that the overall process efficiency is not affected.

The tools developed provide sufficient robustness that we are able to use them on most projects without being restricted by a lack of flexibility.

EXAMPLE OF TRANSLATION PROCESS

The process of developing translation software requires an understanding of two issues. The first relates to the way in which the two software packages require their information and the second relates to the way in which the geometric data is actually written within the geometry storage files.

It is also important to understand what information is relevant and what is not.

Given below is an example of how a cube is written in two different formats.

The following format is for a 1m x 1m x 1m box within a Phoenics CFD domain, (Spalding, B. et al, 2001).

```
> OBJ1,   NAME,       Block 1
> OBJ1,   POSITION,    1.000000E+00, 1.000000E+00, 1.000000E+00
> OBJ1,   SIZE,       1.000000E+00, 1.000000E+00, 1.000000E+00
> OBJ1,   CLIPART,    cube14
> OBJ1,   ROTATION24,      1
> OBJ1,   TYPE,       BLOCKAGE
> OBJ1,   MATERIAL,     198
> OBJ1,   ADIABATIC_W,   0.000000E+00, 0.000000E+00
> OBJ1,   ADIABATIC_E,   0.000000E+00, 0.000000E+00
> OBJ1,   ADIABATIC_S,   0.000000E+00, 0.000000E+00
> OBJ1,   ADIABATIC_N,   0.000000E+00, 0.000000E+00
> OBJ1,   ADIABATIC_L,   0.000000E+00, 0.000000E+00
> OBJ1,   ADIABATIC_H,   0.000000E+00, 0.000000E+00
```

The information tells us the object name (Block 1), its position relative to the origin of the domain and the size of the object in the x, y and z axis directions. The remaining information is required within Phoenics and is not relevant for the geometry translation.

If we were to translate this block geometry into Fire Dynamic Simulator we would require the above to be translated into the following format, (McGrattan, K. B. et al, 2002).

```
&OBST XB=1.00,2.00,1.00,2.00,1.00,2.00 / Block 1
```

It is noticeable from the above line of code that represents the block has different numbers to those shown in the Phoenics input above. The two packages use different forms of coding to represent the geometry. Phoenics uses relative coordinates to position objects. Fire Dynamic Simulator uses absolute coordinates to position objects.

To obtain a correct translation between the two pieces of code, the translator must know where the origin is and also calculate absolute coordinates for the geometry before writing the geometry data into the FDS format in a new file.

The translation tools we have developed ignore information relating to the material properties and other information within the base model. We concentrate solely on the translation of the geometry. Further information can also be incorporated into the translation procedure but the added complexity involved in the programming of such information was seen to outweigh the benefits.

Object oriented Visual C was used for the programming of the translation suite.

INTEROPERABILITY OF SIMULATION AND DESIGN TOOLS

Over the last ten years, initiative has been taken in the construction industry to develop an industry standard format for storage of data relating to the building on construction projects.

The ultimate goal of this initiative is to see a variety of software vendors providing import/export facilities for an internationally recognised class system for data storage. This will allow all information relating to a building that is used in simulation to be read in from a common database file and used by all parties on the project team.

This approach is ideal and should seamless integration of software tools used for building simulation and design be achieved, this would be a great resource for the industry. Currently in the UK construction industry, software developers are only just becoming aware of such technology and initiatives. To date, there is no single vendor of the required software that is able to provide the capability to read or write to such database formats.

One vendor is currently undertaking a research project to determine the viability of incorporating the IAI IFC system into their software. However the industry procures software from many vendors.

Although steps are being made in the right direction towards having seamless interoperability between different software packages, currently the UK market lacks software that can actually achieve such results.

Until the software vendors are satisfied that the benefits of being interoperable are advantageous to their business, it is still necessary to use different software packages and create many models. As a result we have developed translation tools that are simple enough for every day use here and now.

PROJECTS WHERE TRANSLATION TOOLS AND TECHNIQUES HAVE BEEN USED

Nearly all building projects designed by our team now use the technology discussed to some extent. The following list of projects indicates what tools where used, how the process was conducted and what simulation was conducted.

1) Newcastle Schools

   STEPS and Phoenics used for fire engineering. A model was built in IES modelIT. A gem file was exported from IES. The GEM file was imported into STEPS. The GEM file was converted to STL format for importing into Phoenics.

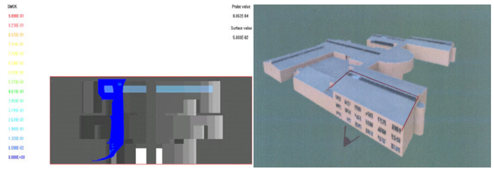

Figure 1. Newcastle Schools models

2) Newcastle Airport

   STEPS for circulation modelling. IES ModelIT was used to build a 3D model. The IES model was exported to GEM format and then imported into STEPS.

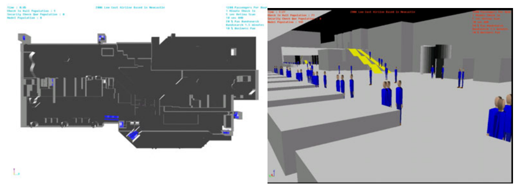

Figure 2. Newcastle Airport models

3) Wembley Stadium

   IES for thermal analysis, Phoenics for fire and smoke movement and STEPS for circulation and escalator performance. IES ModelIT and Autocad used for building model.

Figure 3. Wembley Stadium models

4) Farringdon Station, London

   CFX for wind, fire and rain simulation. AutoVIS for artificial lighting, daylighting and shading analysis. CFX model was exported to STL and then imported into AutoVIS.

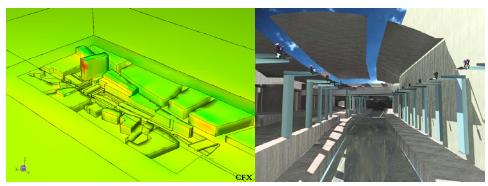

Figure 4. Farringdon Station models

5) Manchester Civil Justice Centre

   IES used for thermal analysis. Phoenics used for thermal analysis, wind simulation and fire engineering. STEPS used for evacuation analysis and circulation analysis. A model was built using IES ModelIT.

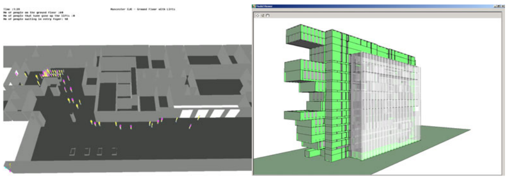

Figure 5. Manchester CJC models

This model was used in IES for thermal modelling. It was also exported out as a GEM. Certain parts of the model where translated to Q1 format for use in Phoenics. The overall building was included in an existing site model in AutoCAD and then exported to STL from AutoCAD. This STL was imported into Phoenics for wind modelling. Certain parts of the IES GEM file where imported into STEPS for ciruculation and evacuation analysis.

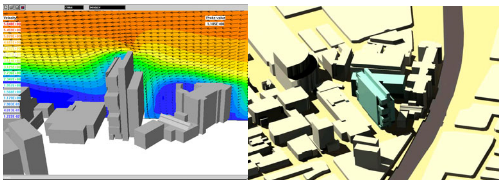

Figure 6. Manchester CJC models

6) University of Luton

IES for thermal simulation, STEPS for evacuation simulation, FDS for fire engineering. A 3D model was built up in IES and a GEM was exported from IES and imported into STEPS for evacuation modelling. The GEM was also translated to FDS. Thermal anaylsis was conducted within IES.

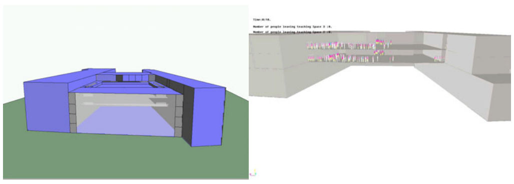

Figure 7. University of Luton models

CONCLUSION

The development of a suite of software tools that allow the translation from one geometry format to another allows increases in base efficiency on simulation of building environments.

The tools and capabilities associated with them allow design concept simulations to be conducted very early in the building design process. Feedback from early simulation can provide a positive impact on the ultimate performance of a building's design and consequently through its operational life.

ACKNOWLEDGMENT

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Assistance provided by IES's support team and Dr Don McLean of IES has also been beneficial in the resultant performance of the translation tools that have been developed.

REFERENCES

McGrattan, K. B. et al, 2002. Fire Dynamics Simulator (Version 3) – User's Guide, issued as part of FDS Software Download from www.fire.nist.gov3

Spalding, B. et al, 2001. Phoenics-VR Reference Guide, CHAM Technical Report TR/326, issued with software by vendor. Information also available at www.cham.co.uk.