Visualisation of Photovoltaic Clad Buildings

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Abstract

This paper describes a study carried out to investigate the capabilities of computer aided design software for the visualisation of building elevations and detail, with focus on the representation of photovoltaic cells in facade architecture. The development of photovoltaic (PV) technology, converting energy from sunlight into electricity, has resulted in the emergence of PV as a building material. This has generated much debate on the aesthetic implications of PV integrated buildings. PV introduces a particularly complex set of requirements not present in traditional cladding materials. As well as the physical characteristics of the material, there is a need to consider factors such as orientation to the sun, and shadows cast by neighbouring buildings. Architects, engineers, developers, clients and the general public all need to be able to visualise proposed designs, either of new or refurbished buildings. This study investigates both the process and end results of computer visualisation in the context of photovoltaic clad buildings.
KEYWORDS: Visualisation, PV, CAD evaluation

1. Introduction

Architects of to-day have a great number of design tools at their disposal which can help in the study of the visual impact of buildings in their surroundings. They are also faced with a growing choice of building materials, and an increasing awareness of the importance of energy conservation. The development of photovoltaic technology has resulted in the emergence of PV as a building material, and has resulted in much discussion [1],[2],[3] on technical performance, cost, and aesthetic implications of PV integrated buildings. Sustained interest in PV clad buildings is being shown from architects, building engineers, building developers, clients and owners of buildings, who each have a need to visualise proposed designs. This paper describes a study carried out to investigate the suitability of computer programs capable of the visualisation of building elevations and detail, and to evaluate selected programs for the representation of photovoltaic cells in facade architecture. The research used two case studies, chosen to reflect issues of communication as well as visualisation. Criteria for assessing the effectiveness of both the process and end results of the visualisation are discussed.

2. Identification of Computer Software

The identification of potential software involved establishing criteria against which the software was to be evaluated, and forming a check-list of the leading features of each program. The leading features identified were:

- Author, distributor, country of origin
- Number of users in the UK Construction Industry and world-wide
- Hardware requirements
- Cost (hardware and software)
- General features (modelling capabilities, simulation techniques)
- Links to other software (via DXF, DWG, IGES file formats)

From an initial identification of twelve programs considered to be of interest, a shortlist of three was obtained by a process of outline evaluation and filtering. These filters, based on the initial program criteria were defined as:

- Basic modelling capabilities
- Visualisation capabilities
- General exposure and use
- Potential for use

AutoCAD and 3D Studio were selected for evaluation, AutoCAD because of its compliance to standards, plus a significant number of users world-wide, and 3D Studio for evidence of its capabilities in enhancing architectural visualisations produced initially in AutoCAD.

3. Evaluation of Software

The evaluation of the software involved two case studies, both undertaken by one post graduate student using a 486 IBM compatible personal computer with 16mb RAM, 540mb hard disk and 2mb Video RAM. AutoCAD AEC (release 12) and 3D Studio version 4 were the software packages evaluated.

The initial evaluation involved the creation of a three-dimensional model of a subject building, with particular emphasis placed on the visualisation of the exterior. The building modelled was the Northumberland Building on the campus of the University of Northumbria at Newcastle. The south facing facade of this building was reclad during the summer of 1994 with PV modules architecturally integrated into the cladding [4]. This project was funded by the CEC's THERMIE programme on the promotion of energy technology, together with UK Government support and private sponsorship. The building has provided a focus for architects, engineers, and other professionals to discuss the implications of integrating PV into their designs.

Methods of modelling PV panels were explored. A detailed geometric model of a PV panel was created and rendered then compared to a model produced using simpler geometry and material mapping techniques.

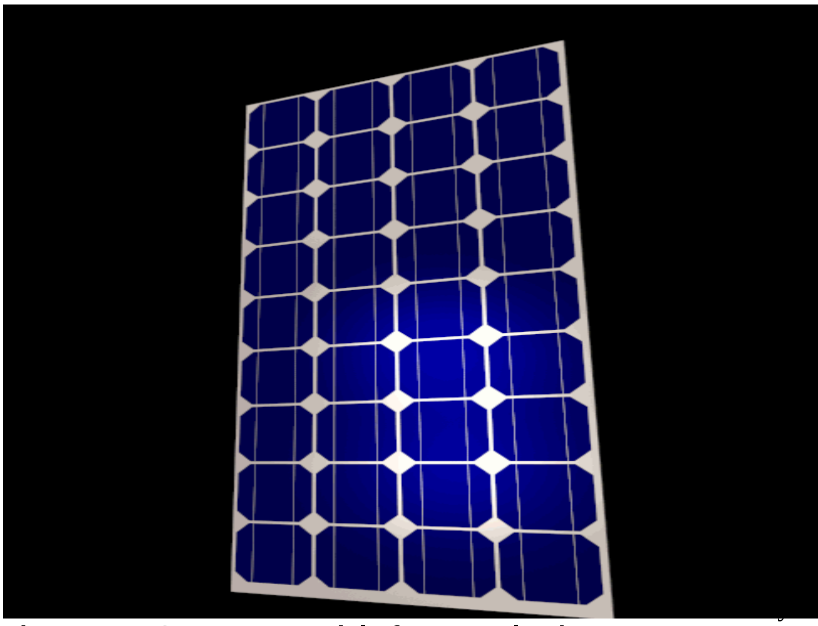

Figure 1 Computer model of PV panel using geometry

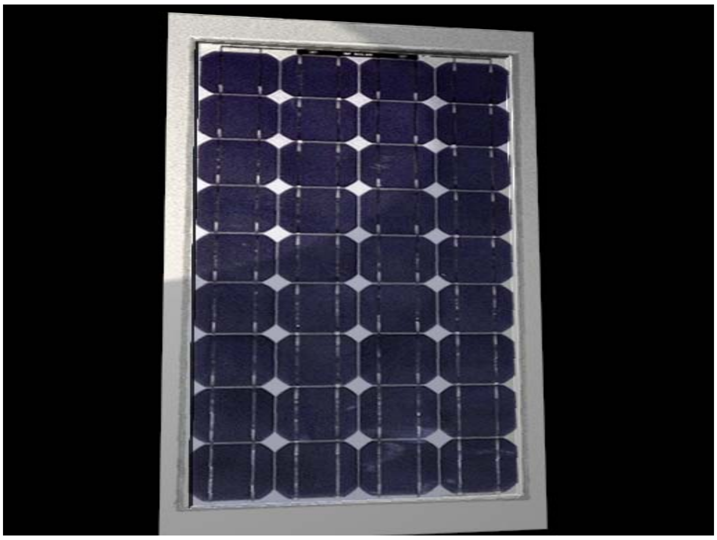

Figure 2 Computer model of PV panel using simple geometry and photographic mapping

Rendering times were compared by creating arrays of 25 and 625 PV panels and are shown in Table 1.

	Rendering Time (seconds) 1 panel	25 panels	625 panels
Photographic	56	74	98
Geometric	108	140	1587

Table 1 Rendering times of PV panels

isualisation of Northumberland Building used a f simple geometry with an image mapped onto total of 460 panels were used on the south s method reduced rendering time significantly.

three-dimensional computer model of the was modelled initially in AutoCAD, by referencing existing AutoCAD 2D plans, d elevations of the building, which existed in ormat. These provided accurate references on base the 3D model. Drawing efficiency was y making full use of AEC's levels and layers. -frame models of the building were created, after refurbishment.

odels were then imported into 3D Studio for ring. Surface characteristics, colour, reflection e were added to the model and a range of s produced, looking at the building from ngles, distances and perspectives. Shadows eighbouring buildings were also simulated (Figure 3).

Figure 3 Computer model of Northumberland Building

Further evaluation of the software continued using a second case study. In order to assess the visual impact of photovoltaic cladding in an urban environment, a three-dimensional model of a street in Newcastle was created, again concentrating on the visualisation of exterior facades. The street modelled was Northumberland Street, which is typical of many city streets in the UK and elsewhere in Europe. It contains a combination of commercial offices and shops, with a great variety of architectural styles. Some of the building facades are already clad with highly reflective, glass-like material, whereas other buildings are very traditional and have facades of architectural interest.

The data for the computer model of Northumberland Street originated from the technique of photogrammetry, gathering three-dimensional information from aerial photography to form a digital ground model [5]. This data was converted into a form suitable for three-dimensional modelling, and additional geometry was added to it in order to create a more realistic street scene. The street was modelled and certain buildings were selected to illustrate the effects of recladding parts of their facade with PV. An architectural walkthrough of the street was produced with 3D Studio, and this has been put on to video for presentation purposes.

In order to prevent the geometry of this street scene becoming over complex, photographic images of the building facades were mapped onto the geometric faces. Photographs of building facades, developed in the form of PCD files on Photo CD, were read into an image editing program, and distortions due to perspective, obstructions in the street etc., were removed prior to mapping onto the 3D faces.

Figure 4 Computer model of Northumberland Street

The street scene was modelled with lights, cameras and backdrops to view the scene from different viewpoints, and to simulate sunlight.

Certain buildings were modelled to show the effect of integrating PV into their facades, enabling before and after comparisons to be made. Different colour possibilities of PV can be discussed, and aesthetic implications considered. The addition of reflective characteristics to certain faces added to the realism of the images. Figure 5 compares the images of a selection of facades in Northumberland Street. The images on the left are from photographs, those on the right are from the computer model, during its various stages of construction.

4. Results

The end results of visualisations are usually presented simply, there for all to see. The computer model of Northumberland Building has provided a way of comparing an actual building with visualisation techniques based on photography, artist's impression [6] and computer simulation (Figure 6).

Figure 5 Comparative study of images of building facades in Northumberland Street

Figure 6 Comparative study of visualisation techniques

The model of Northumberland Street provided a way of viewing the street as it presently exists, and then assessing the impact of proposed changes. Any new building designs can be viewed from different viewpoints enabling planners and researchers to assess the effect of new proposals. The varying disciplines of those needing to visualise PV designs result in the images being looked at from different professional as well as geometric perspectives.

Results of this research demonstrated that the programs evaluated were able to produce acceptable images, of both single buildings and buildings in a street context, and that the process of the visualisation could be replicated on other CAD models, of both new or refurbished single buildings, or of city centres. Criteria for judging the effectiveness of the visualisations were summarised as follows:

- Were the end results based on *credible* data?
- Were the end results *comparable* with other methods of architectural visualisation?
- Were the processes that produced the end results *reliable*?
- Were the end results able to *communicate* design options to interested parties?
- Could the end results be obtained within time and resource constraints *typical* in many offices?
- Could this visualisation process be *repeated* by someone else?
- Could the visualisation process be applied to a more *generalised* study?
- Could the visualisation process be *applied* to a real life setting?

5. Conclusions

The importance of energy conservation in to-day's world will be a major factor in furthering research into PV integrated buildings. This study has offered a critical evaluation of commercially available, industry standard CAD software in the context of the visualisation of photovoltaic clad buildings. It argues that the use of PV as a building material introduces a particular set of criteria not present in traditional cladding material, and has justified this study, which has related to issues of communication as well as computer graphics. The representation of design options to interested parties, using software typical of that used in many design offices, has raised the following issues:

- Whilst a representation of PV can be based on very accurate geometry, the simulation of surface properties, such as colour, texture, reflection and shininess can only be represented approximately, using a similar technique to an artist's palette. Precise values, relating to physical characteristics, were not possible to define

- Simulation of sunlight is not entirely accurate with the tools available in 3D Studio. The end results of shadows cast had no numerical data attached to them for further environmental analysis. This will limit the uses of the model for other purposes, such as calculations into electricity generation from a PV facade.

- The representation of PV integrated buildings in an urban environment resulted in a model with geometrical limitations. The application of photographs to faces in the geometry, to represent building facades, is being used in many other visualisation projects. This study argues that the suitability of this technique as a design tool will depend on the needs of interested parties in the design process.

Conclusions are that the programs evaluated in this study can contribute to the visualisation of photovoltaic clad buildings. They are able to present a range of images which represent design options to multi-discipline teams, thus furthering the exchange of information and ideas between different professionals. The level of geometric modelling necessary to represent design options, and the numerical data supporting the visualisation depends on the needs of the interested parties. Photovoltaics in buildings is a technology which will result in much discussion between different parties at the design stage.

This study has shown that CAD models, originally produced for one purpose, can be usefully employed for visualisation purposes. We should harness effectively the availability and ability of CAD tools to ensure that the aesthetic aspects of the design of PV integrated buildings are considered by all concerned with our built environment and the conservation of energy in the world to-day.

6. Areas for future research

- To look at programs such as Radiance [7] whose performance and functionality is of interest to those in the field of the visualisation of photovoltaics.
- To follow developments in commercially available computer programs, and evaluate their role as design tools for building integrated photovoltaics.
- To look at the object-oriented approach of representing both graphical and non-graphical information in a computer model.
- To contribute towards the training and dissemination of information on design tools in relation to building integrated photovoltaics.

7. References

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