VISUAL IMPACT ANALYSIS—MODELLING AND VIEWING THE NATURAL AND BUILT ENVIRONMENT

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1.0 THE APPRAISAL OF FORM AND FABRIC

For some years now, the visual impact of buildings on the landscape has been a contentious issue at many public planning inquiries. This reflects the underdeveloped state of objective visual appraisal, particularly in the clear presentation of the harmful and enhancing effects of building proposals on the local environment. Notably, the accuracy and realism of traditional visual assessment methods has been called into question.

This must be of concern to the environmental design professions, since Environmental Impact Analysis will continue to place significant demands on the rigour of assessment procedures. Thus, at a time when rural landscapes are coming under increasing pressure from industrial developments, project decision makers cannot afford to make judgments on insufficient, inappropriate, or inaccurate visual evidence.

This study is concerned with a new generation of computer-based models which predict, accurately and meaningfully, the visual impact of buildings and other constructions on their urban or rural environment. As such, they form part of the increasing repertoire of CAAD techniques which allow designers to appraise, and thereby select from, alternative design options.

The computer-based appraisal of design options may be seen in systems terms (Fig. 1). Typically, CAAD software will predict, for any design hypothesis, a wide range of performance consequences—economic, functional, or environmental. Input to the model, i.e. the design hypothesis, consists of the proposed form (i.e. geometrical layout) and fabric (i.e. constructional choices) of the building. As it turns out, this input data is every bit as relevant to the visualisation of the building as it is to the prediction of its cost, energy consumption, and operational efficiency.

It is thus possible to create a suite of computer programs, each operating on a shared description of the building form and fabric, which allows appraisal of the aesthetic qualities as well as the economic, functional, and environmental qualities of the building. Such a suite is represented in Fig. 2.

The program GOAL (General Outline Appraisal of Layouts) outputs a profile of cost and performance measures; the building geometry is passed from GOAL to BIBLE [1] which generates wire line perspectives from any viewpoint. BIBLE in turn, passes the geometry to VISTA [2], which generates, for any sun position, fully coloured, textured, and lit perspectives.

2.0 PROGRAMS FOR VISUALISATION

The programs, BIBLE (Buildings with Invisible Back Lines Eliminated) and VISTA (Visual Impact Simulation, Technical Aid), offer the designer a two-staged approach to visualisation. The first stage is the production of wire line perspective views; these may be perfectly adequate where issues of visibility predominate or where the object has a skeletal structure (e.g. electricity pylons). The second stage is the production of fully coloured, textured, and lit perspectives; such views are necessary where issues of visual quality predominate.

2.1 BIBLE

The user interface of BIBLE (Fig. 3) is designed to be as easy for the inexperienced user as possible, without sacrificing the capability to specify arbitrary projections. This is achieved by four features.

(a) Fail-safe design: any invalid or wrong input produces an English-language error message, apologising for the program's inability to understand the input provided and explaining what sort of input was expected, or what options were available to the user at that point.

(b) Graphical specification of viewpoint. This allows the user to point on a displayed plan view to...
a place in the vicinity of the building(s), and in effect, ask 'What does it look like from here?'
(c) Use of default parameters: all the view control parameters have default values computed by the
program for each data set as it is read in. Thus it is possible simply to read the data file and immediately
call for a view, and get a meaningful picture.
(d) A command menu on the screen gives the user a visible reminder of what he can do without verbose
prompts, and more detailed information can be obtained by selecting the HELP command.

The user-specifiable view parameters and default values are as follows:
(a) The Eye Point from which the scene is viewed may be any point \((X, Y, Z)\), inside or outside the
region containing objects. \(X\) and \(Y\) may be specified graphically. The default is 'a long way away' in \(-X, -Y, +Z\).
(b) The Focus Point which is the other end of the line of sight may be any point \((X, Y, Z)\). \(X\) and \(Y\)
may be specified graphically. The default is the middle of the scene. The focus point may be moved
in order to obtain two-point perspectives or views of off-centre parts of the scene.
(c) The Mid-point (of the resulting picture) may be any point \((X, Y, Z)\). \(X\) and \(Y\) may be specified
graphically. The default is the middle of the scene. The mid-point is normally set the same as the focus
point, but it may need to be different for two-point perspectives or nonorthogonal parallel projections.

Hidden lines may be removed (which is the default), drawn dashed, or left in. The projection may be
perspective (by default), partially perspective (parallel verticals, parallel horizontal), or orthogonal. Output
may be to a display file, to the terminal screen, or to a plotter scaled to A1, A2, A3, or A4 size; output
device selection is dynamic and may be changed between pictures.

A major facility offered by the program is that of producing views which can be automatically super-
imposed onto site photographs. The user simply specifies the camera position, the focal length of the
camera lens and the enlargement of the photographic print; the resulting view is correctly scaled, positioned,
and proportioned for the photomontage.

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**Fig. 2.** The inter-relationship, in terms of data input/output, of the three programs GOAL, BIBLE and
VISTA.

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**Fig. 3.** BIBLE: the menu of commands, plan and default values which allow ready specification of viewing
parameters.
2.2 **VISTA**

VISTA may be classified by describing it as a 3-D colour perspective package with hidden surface elimination; it may be used to model any artifact composed of planar surfaces [3]. Although wire line perspectives, as produced by BIBLE, can be very valuable aids to visualisation, they lack realism and require more interpretation on the part of the user. The use of colour to fill the surfaces improves the 3-D impression, particularly if the surface colours are predicted by a simple lighting model and even more so if shadows are generated.

The outline structure of VISTA is shown in Fig. 4. The VISTA database contains a hierarchically structured definition of the geometry of the model. This definition is similar to the BIBLE geometry definition, the model is composed of Bodies which contain planar Faces. In addition to the BIBLE type description, VISTA allows another level of detail to be associated with each Face, these are known as Tiles, and may be used to model areas of different colour or features such as windows and doors on the face of a building. Because of the close relationship between the geometric data required by both BIBLE and VISTA, the VISTA database is created from a BIBLE data file by running the interface program BIVVIS. The reasons for creating VISTA geometry as a BIBLE data file are as follows—a large number of examples already exist in BIBLE format; programs for creating BIBLE geometry already exist; if the

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**Fig. 4** The structure of the VISTA suite of programs.
geometry exists in BIBLE format, then it can be run by both programs. In addition to the geometrical description of the model, the VISTA database also contains the colour details for each Body, Face, and Tile in the model.

Shadows are created by running the hidden surface algorithm using the light source position as the eye position. The visible areas are illuminated by the light source and the invisible areas are in shadow. The visible areas, known as Patches, are stored in the database and may be retrieved on subsequent views to display the shadows from the defined light source. In the current implementation of VISTA, up to ten shadow studies may be stored in the database and up to five shadow studies may be retrieved for any view. Figure 5 shows a simple example of the interaction of two shadows.

One of the most important aspects of a package such as VISTA is the interface between the user and the colour model within the package. This interface is becoming increasingly complex as the colour palette of the latest colour terminals becomes very large (typically 16.8 million). Since most colour devices use the RGB colour model for defining colours, most lighting algorithms have evolved around the model, and VISTA is no exception. Although the RGB model is very easy to understand, most people find it very difficult to express colours in terms of Red, Green, and Blue. Because people with different backgrounds, in terms of their use of colour, will be familiar with different types of colour model, the colour interface routine VISCOL has a number of different colour models from which the user may make his choice of colours. These models are as follows—Red, Green, Blue (RGB); Cyan, Magenta, Yellow (CMY); Hue, Lightness, Saturation (HLS); Hue, Value, Saturation (HVS); British Standard Colours (Fig. 6). Each of the selection modes allows the user to view the chosen colour before entering it into the database. In addition to the variety of colour models, other options allow the user to manipulate the colour space to give him a guide to accurate choice of colour, i.e., sections of constant hue from the HLS model. Another feature allows the user to create a file of colours and then retrieve from that set by name rather than by value, this ensures that the same colour is used throughout rather than use memory or guesswork to match colours. Another application of this feature is to use it to define the range of colours given by paint manufacturers.

VISTIL is the module which allows the user to create and manipulate Tiles. This is achieved by transforming the target face to a normalised view and then defining the Tile as a polygon either by cursor or by inputting as local coordinates, the Tile polygon is then transformed back into model coordinates and stored in the database. Tiles may be copied from face to face or from body to body either singly or in groups. An example of the use of Tiles to model texture effects is shown in Fig. 7. This is achieved by using a special type of tile, known as a Grid Tile, which is repeated over the surface in question. Other definable parameters allow the user to randomize the colour of the tiles within a given tolerance.

The VIEW module is the heart of the VISTA package; it performs the perspective transformations, the hidden surface elimination and the colour rendering. It takes as input the description of the model as defined by the VISTA database and the required viewing and lighting parameters. The viewing parameters consist of the type of view required i.e. bird's eye, camera, etc., and the eye and focus positions. The lighting parameters specify the position and spectrum of any light sources (in RGB) and whether any shadow studies are to be retrieved. The lighting model in VISTA allows the user to model the ambient, diffuse, and specular components of any light source, and also to vary the ratio of ambient to direct light available from that source. The output picture is written to a display file and not directly to a colour output device. This has several advantages, the most important of which is that the VIEW module can be totally device independent.

3.6 CASE STUDIES

The computer methods outlined above allow a thorough evaluation of design decisions, and have been used in earnest in a number of projects to elicit informed judgments taken by both designers and lay audiences at inquiries. Such repeated application of the programs to live projects has, naturally, indicated new directions for program improvement (user interface and output features) and stimulated continuous revision and reappraisal of program capabilities.

3.1 Hilton Hotel, Edinburgh

Visual modelling by computer in an urban context may include representation of the surrounding townscape in addition to the study building. Figure 8 shows the winning entry to a competition for a Hilton Hotel (unbuilt) in Edinburgh. The townscape model was constructed photogrammetrically by digitizing points from aerial stereo pair photographs; while the geometry data describing the study building were hand-keyed alphanumerically. Using the program BIBLE, views of the proposal were generated to simulate its impact on the urban environment. Digitizing the context environment, whether urban or rural, can be a laborious and frequently unnecessary focus of effort, especially if it is to remain unaltered. In such cases, well-established photomontage procedures would be a help; these would capture the context view on photographic film and the computer generated perspectives may be drawn or overlaid on top. Nevertheless, very few CAD perspective packages are calibrated or equipped to measure up to the standards of veracity and comprehensive visualisation. For example:

- in long range visualisation (over 2 miles), the earth's curvature and light refraction can affect the position of objects as seen by an observer,
- optical and other camera distortions can cause a mismatch in computer-based photomontaging.
Fig. 5. Interaction of shadows from two light sources modelled by VISTA.

Fig. 6. The range of British Standard Colours held in the VISCOL module.

Fig. 7. An example of the use of Tiles in VISTA to model texture effects.
The accuracy of the photomontage process using BIBLE has been established and high degrees of control are respected in project work.

3.2 Power station, Hong Kong

It is imperative to know the viewpoint location in the course of constructing a photomontage. In this case, a second power station on the Hong Kong mainland at Castle Peak by the architects Robert Matthew and Johnson Marshall, a number of the viewpoints of the site photographs were unknown, having been taken from a ferry and a helicopter. The building geometry was assembled and prepared for viewing by the program BIBLE. The onshore photomontages were drawn. To locate the XYZ viewpoint coordinates of the offshore and aerial photographs, a program was devised to iteratively search back to the correct observer position. This procedure was based on a triangulation method with two known objects in the photographs and the computer views, and the viewpoint acting as the variable. Finally, the accurate wire line perspectives (Fig. 9) and the colour site photographs formed the basis of a set of unfinished colour montages by a perspective artist.

3.3 Hitchin Priory development, Hertfordshire, England

The presentation of visual evidence as a planning inquiry can win or lose aesthetic decisions. In this case, the client, a life assurance company, was proposing an office development in a sensitive semirural landscape and required high quality visual material to put before a local planning committee. The programs BIBLE and VISTA were employed to address two problems:

1. building scale in relation to adjacent housing (BIBLE); and
2. building colour in relation to existing brickwork colours (VISTA).

Photographs from a number of vantage points around the site were recorded, and a selection made therefrom for computer montaging: black and white and colour print film were used. The geometry data files for computer processing were compiled from 1:200 scale drawings of the proposed building and an existing wall, surrounding and intersecting the site. Control point information, known site features and surveying poles, were included for each view and surveyed in reference to the O.S. grid to the nearest 100 mm. Seventeen BIBLE wire line montages were drawn on acetate and overlaid on the black and white site photographs. The program VISTA was then used to generate colour views of the proposed development.

In certain cases, the foreground tracery of trees or shrubs partly obscured views of the building. The difficulty of achieving a montage in such cases is, in effect, the problem of how to slip the computer view in behind relevant foreground, yet in front of background, objects. In overcoming this problem, colour transparencies of the site photographs were overlaid on the computer VISTA views: background objects which were hidden by the building were required to be edited out of the transparency. The two images combined were then rephotographed on a light table for subsequent presentation (Fig. 10). Colour control was extremely difficult to achieve due to lack of control in the colour printing process. In addition to the computer-based montages, a number of artist’s impressions were drawn for presentation purposes.

The most time consuming part of this work is in the construction of the two-point perspective such that the drawn building matches the position of other site objects in the photographs. This setting up procedure for the perspectives was obviated by the use of the computer wire line perspectives. More attention was, therefore, devoted to the rendering of the final perspective, knowing that the building location and scale were accurately drawn already. Two main areas of concern resulted from this study:

i) Data inaccuracies. Incorrect reportage of survey data identifying viewpoint and control point information caused lost time in rechecking and reprocessing the computer views.
ii) Overlaying. The difficulty in effecting a realistic colour montage when views of the development are interrupted by foreground features, still remains unresolved unless time-consuming hand-crafted methods are used. This runs against the idea of speedy computer-based visualisation. An automated solution to colour montage is being sought.

3.4 Department of Architecture, Strathclyde University

Ultimately, the validity and usefulness of a modelling aid will be measured against its ability to predict reality. This retrospective visual appraisal of a building was intended to verify certain modelling features of the program VISTA. A particular view of the Architecture building at Strathclyde University was chosen and the time of day and sun position recorded, in addition to the regular viewing parameters. The BIBLE geometry data file of the building was converted to a VISTA data base and surface colour specifications compiled. The simulated situation was then generated on the AED 512 colour terminal and compared with the actual view (Figs. 11a and b).

Some of the problems encountered in the study included:
- the modelling of foreground landscape;
- the simulation of window glass and other reflective materials;
- the weather staining of building surface materials;
- the need to model facade detail at different levels depending on viewing distance;
- the need for shadow intensity variations—
  a) across surfaces, caused by diffuse light;
  b) dependent on climate, e.g. sunny or overcast days.

Notwithstanding these difficulties in the scene, the level of realism achieved in visualisation is eminently acceptable to architects in the process of design.

4.0 FUTURE DIRECTIONS

There are a number of issues around which future developments in modelling and viewing the environment will be focussed.

4.1 Lighting models

Exterior viewing presents few problems with respect to simulating the lighting conditions. Not only is there only one point source, the sun, but it is far away. When modelling building interiors difficulties arise in simulating correct illumination levels for multiple light sources, and the proximity of their location to surfaces and the observer.

4.2 Photomontaging

In certain cases, the accuracy of photomontages has been called into question. In particular, it was suspected that optical camera distortions may give rise to discrepancies between the site photograph and the modelled image. A thorough investigation into the issue of accuracy in visual assessment has been conducted, enabling the BIBLE program to be properly calibrated and verified [4]. Factors affecting long range visualisation, such as the earth’s curvature and light refraction, were examined and accounted for in the program logic. The study objects, existing electricity transmission towers in an undulating rural landscape, proved a rigorous test for program accuracy.

In cases where it was difficult to identify the critical viewpoint locations for photomontaging, resort may be made to the program VIEW [5], in which contours of visibility may indicate the frequency of object visibility within the surrounding landscape.

4.3 Foreground/background

The difficulties encountered in the Hitchin case study regarding foreground landscape interference will be overcome through technological improvements. Hopefully, image handling and mixing through the use of a frame grabber will allow a higher quality merging of site and computer images.

4.4 Copying and reproduction

Maintaining the correct colour balance and quality of hardcopy reproduction from graphics terminals has consistently proved to be a stumbling block in the presentation of accurate visual evidence, especially when building surface colours and textures are under examination. In the same manner, research dissemination in this field is fraught with reproduction difficulties; even within this study uncertainty exists as to the fidelity of the colour graphics reproduced. Significant improvements in the copying and reproduction of colour computer graphics for visualisation in architectural design are required if the benefits of building detailed simulation models are to be properly harvested.

4.5 Application in the design process

Many techniques for visual assessment are initiated in the later detailed stages of design work. In contrast, there is a greater need for methods and models to be developed and applied at the earlier outline stages of design, where the major visual design decisions are normally taken. Computer-based models seem best structured for continuous application throughout design from inception to completion, and beyond in terms of visual resource management in future planning and landscaping.

REFERENCES