Thomas W. Maver
Jelena Petrić

University of Strathclyde
Department of Architecture and Building Science, ABACUS
131 Rottenrow, Glasgow G4 0NG, UK
Tel: +44 41 552 4400 ext. 3997, Fax: +44 41 552 3991
e-mail: abacus@strath.ac.uk

PREDICTING VISUAL IMPACT
Computer Aided Visual Impact
Analysis

The two related questions which need to be answered in any visual impact analysis are:

- what will be the degree of visibility of the proposed intervention in the urban or rural landscape, and

- what will the intervention actually look like in the context of the landscape from any particular viewpoint.

2.1. The Modelling of Geometry

Central to any computer aided visual impact analysis which attempts to answer these questions is the modelling of geometry; the geometry of terrain, the geometry of vegetation and the geometry of the constructions which already exist and which are proposed.

2.1.1. Terrain Models

The data acquisition for computer based models of terrain is important as it affects the fidelity and the degree of realism which can be obtained in any computer generated visualisations of land form. There are four main sources of data:

- field surveying techniques using electronic tachometers and data collectors; this demanding procedure is appropriate where high accuracy within a limited area is required.

- digitisation of Ordinance Survey contour maps, carried out manually or automatically, either by line-following or raster-scan algorithms; this approach offers an economical compromise between accuracy and large scale application.

- aerial photogrammetry which utilises either analytical stereo plotters or instruments for orthographic projection; this approach is suitable only for relatively large scale applications.
- satellite remote sensing which analysis reflected and emitted radiation from the earth's surface; this technology has the potential to generate reasonably accurate data over very large areas.

Fig. 2.1.1.1
Terrain surface "texturing" using fractal surface interpolation. ($\alpha=0.1$)

Fig. 2.1.1.2
Terrain surface "texturing" using fractal surface interpolation. ($\alpha=0.5$)

Fig. 2.1.1.3
Fractal surface interpolation with all the surface points plotted but not connected into the grid. ($\alpha=0.9$)

Fig. 2.1.1.4
Terrain surface "texturing" using fractal surface interpolation. ($\alpha=0.9$)

Whatever the origin of the data, it is eventually stored in the computer, for the purposes of a digital terrain model (DTM), as $x$, $y$ and $z$. 
coordinates, i.e. easting, northing and level, either on a regular rectangular (x, y) grid, or randomly located. There are many DTM software packages which can convert such data into three dimensional perspective views of the landscape, represented either as connected planar triangles or rectangles. The scale at which the vertices of the triangles/rectangles is set, coupled with the reliability of the source of the data, obviously determines the accuracy of the visual image created.

The impression of visual accuracy can be enhanced by the "texturing" of the planar geometry through the application of fractal generation. Natura terrain exhibits the property that, as one views its surface at greater magnification, more and more structure is revealed; fractal sets exhibit exactly this property. It is possible, therefore, through simple mathematical intervention, to "roughen" the planar geometry generated from the DTM data to provide a spurious but helpful 'realism' to the DTM.

Rather more importantly, available DTM software packages can carry out geometric operations which are crucial to the analyses of visual impact. These include one based largely on the principle of intervisibility i.e. if an observer at position A can see an object at position B, then an object at position B can be seen by observers at positions A i-j.

Sophisticated software packages are now available which will generate "contours of visibility" from digital terrain models. The user identifies the position within the DTM of the proposed object (e.g. a chimney stack) together with its height above the DTM surface; the software "looks out" radially from the top of the object and "sees" all visible points on the surrounding landscape. The "visibility contours" thus generated can be plotted as a "visibility map" which informs the architect/planner as to which viewpoints, i.e. those habitations, sections of roadway, etc, which may be worthy of further investigation and from which computer generated views of the object(s) might be produced.

2.1.2. Vegetation Models

The geometry of vegetation is exceedingly complex in its variety and its seasonal and temporal variation. The current approach is to operate a mathematical model which is faithful to the botanical nature of trees and
recognises their branching and growth. This requires the mathematical models to incorporate the following features:

1. integration of the botanical knowledge of the tree-architecture: how they grow, how they occupy space, where and how leaves and flowers are located.

2. integration of time which enables viewing the ageing of a tree. It includes the possibility to get different pictures of the same tree at different ages, and simulate seasonal variation.

3. integration of physical parameters such as gravity, wind, plantation density, etc.

The perceived realism of advanced models is extremely high, as are the computational overheads. In most visual impact analyses, however, the primary concern is how mass planting, e.g. by the Forestry Commission, will impact on visibility (or in-visibility) of distant landscape scenes and horizons; in such cases a crude 3-D model of forestry blocks is sufficient to communicate to landscape architects the primary impacts on the rural environment.

Figs. 2.1.2.1, 2.1.2.2
The effect of wind is simulated by a non-uniform deviation with one plant controller.
Figs. 2.1.2.3, 2.1.2.4
The effect of gravity is defined by a uniform deviation parameter.

Figs. 2.1.2.5
A young tree as above with added foliage.

2.1.3. Construction Models

The constructions which women and men place in the natural environment are, understandably, easier to model in a computational environment; they are, largely speaking, composed simplistically of geometry arranged, often, rectilinearly.

There are a number of different ways of representing the constructions which people propose to impose on the landscape.
Wire-Line Representation: In 'wire-line' models, the construction is represented only by a set of vertices some of which are connected to others by lines. Computer algorithms which generate perspective views of 3-D objects have been in existence for nearly twenty years; they accept as data the cartesian coordinates of the vertices of the object together with a list of those vertices which are joined. The algorithm is thus able to deduce the geometry of the planes which bound the object.

The user can then specify the viewing parameters - eyepoint, focus point, cone of vision - and the algorithm computes the mathematics of perspective geometry and displays, on a screen or on a pen plotter, the resulting 'view' of the object.

Given additional information on which planes in the object are transparent and which are opaque, the smarter algorithms, by sorting the places in terms of their distance from the viewer, can suppress the hidden lines thus reducing the possibility of misinterpreting the shape of the object and enhancing the realism of the image. There are occasions however (as will be shown in 2.2) when there is advantage in representing the object only as a set of lines rather than a set of surfaces.

Surface Representation: Wire-line images, with or without hidden line removal, represent plane surfaces only by the lines which bound the surface. In more sophisticated computer models, the user can attach attributes - colour, transparency, reflectivity, texture - to each surface to allow, on an appropriate screen or hard-copy device, a rendered image of the object.

Many computer programs for surface representation have a lighting algorithm which allows the user to illuminate the object with one or more light sources. The software can then cast shadows and render each surface in response to the angle it makes to the 'eye' and to each and every one of the light sources. The degree of realism attained by these models is quite remarkable.

Solid Modelling: Solid modelling, perhaps better termed volume modelling, allows the user to construct the geometry of the object by performing set operations (union, difference, intersection) on a range of parameterised primitive volumes, e.g. cube, sphere, pyramid. The images obtained from solid model representation are similar to those obtained from surface representation.
Figs. 2.1.3.1
A wire-line representation of a site and a proposed extension to the existing village (the only existing building is an old church on the highest point of the ridge).

Fig. 2.1.3.2
A new extension to the village Rezvici on the Montenegrain coast of the Adriat
Figs. 2.1.3.3, 2.1.3.4

Terrain model interpolated from the ordnance survey contours (Rijeka Rezevica).

Fig. 2.1.3.5

A view from the sea of the proposed settlement only. The buildings and the spaces among them modelled with minimum detail. The emphasis is on the dialogue between buildings and public spaces.

Fig. 2.1.3.6

Relationship of buildings to the natural terrain is analysed. The intention was that architecture should "grow" out of the natural setting.
Fig. 2.1.3.7
A photograph of the existing village of Rezevici (Montenegro, Adriatic coast).

Fig. 2.1.3.8
A hand-drawn south elevation of the proposed extension to the existing settlement.

Fig. 2.1.3.9
A hand-drawn west elevation of the new extension to the village Rezevici. Note that the church (on the highest point of the steep site diving into the sea) is the only old building that links the new with the existing.
2.2. Image Mixing

Visual impact analysis is often concerned with the relationship between the existing landscape or townscape and the object which it is proposed to place within it. It is necessary, therefore, to confine, onto one image, the geometry of what exists and what does not yet exist.

If a computer model of the terrain or townscape exists, the computer model of the proposed construction can be recalibrated to the same coordinate origin and scale and thereby merged with the terrain or townscape into one geometrical model.

This single model can then be analysed, as described in 2.1, to identify contours of visibility which may suggest the most important places from which perspective views should be constructed. It may be relevant also to superimpose a vegetation model which allows analysis of how, over time, particular planting strategies can mitigate visual impact.

The advantage of merging computer-based data of terrain, vegetation and construction is the complete flexibility which the user has in choice of viewpoint. The disadvantage lies in the relative crudeness of computer generated images of terrain and vegetation; this may not be a serious disadvantage to professionals, but could prove problematic for the general public.

Where a limited number of realistic images are to be put to the public, the process of photomontage is appropriate. This involves careful photography of the site from each of the critical viewing positions, noting in each case the exact position of the camera, the direction of view and the focal length of the camera lens. These parameters can then be used to generate a computer perspective of the proposed construction which is scaled and positioned correctly in relation to the photographic image.

The conflation of the photographic image and the computer generated image can then be done in two different ways:

i) by obtaining a hard copy of the computer image, cutting round it and pasting it directly on to the photographic print of the site.

ii) by scanning the photograph of the site into the computer and composing, on the screen, the scanned image and the computer generated image of the proposed construction.
Fig. 2.2.1 Computer model of Edinburgh Old Town with a proposed intervention inserted into the urban context.

Fig. 2.2.2 Image mixing by means of computer photomontage (Edinburgh Princess St.).
2.3. Verisimilitude

If computer based visual impact analysis is to be cost effective, it is vitally important to make good decisions on that degree of visual realism which is necessary and sufficient.

In terrain modelling, the size of the triangular or rectangular grid mesh must be chosen in relation to the 'roughness' of the terrain, the scale of the proposed intervention and the distance of the viewpoints from the object. Too large a grid scale may misrepresent the degree of visibility and therefore the visual impact; too fine a grid will entail unnecessary processing time and cost.

The same issues of geometric 'granularity' are relevant to the modelling of the construction itself, whether or not to represent a building, say, as a simple 'shoe-box' or to model the fine detail of form and facade. This decision, together with those concerning the choice between wire-line, grey-scale or fully coloured, shadowed and rendered images is intimately bound up with the nature of the subjective value judgements on visual impact which the professional and/or the layperson is being asked to make.

3. Case Study: Electricity Transmission Line

This case study describes a computer based visual impact study in a highly sensitive rural area of two 33kV wood pole overhead transmission lines to provide electricity to the expanded Stansted Airport.

3.1. Background

In 1985, the Government gave the final go-ahead for a third London Airport which was to be build at Stansted in Essex.

The BAA (formerly the British Airports Authority), initially requested an 8 MW supply at 11kV. This was subsequently increased to 12 MW and required in time for the scheduled opening of the new Airport Terminal in August 1990.

The existing 11 kV system in the area, which also supplies the present Airport, is a typical rural overhead distribution system and in need of some reinforcement.
From system loss and reliability studies, it was clear that the optimum supply for the new Airport and reinforcement of the existing system could be achieved from the west by erecting two single 33 kV wood pole overhead lines from the Bishop's Stortford grid to a new 33/11 kV primary substation on the perimeter of the Airport. The decision to use overhead lines was clearly one of economics and convention. The additional cost for undergrounding would have been £1.25 million.

Fig. 3.1.1 Computer photomontage: a case study of power transmission line in a sensitive rural area of East Lothian (Southern Scotland). Photographs were taken prior to the construction of the transmission line. Computer simulations show a high degree of accuracy when matched with the 'in situ' photos of the constructed line.
3.2. The Environmental Challenge

Having established the most economic way of providing the supply was necessary to assess the impact this supply would be seen to or on the natural environment.

To give some idea of the extent of local feeling towards the Airport, necessary to go back to the 1960's, when a Government study of all usage and future requirements reported that a third Airport locate Stansted should be built. A Public Inquiry was held in 1965 and followed some very well presented opposition from local people on environmental grounds and from other objectors, the BAA's application was turned down.

The Stansted story was reopened in 1979, when the BAA again applied for permission to develop a third London Airport. Another Public Inquiry began on the 15 September 1981, and took twelve months to hear. Inspector dismissed the objections and approved the BAA's application. The Government gave its final blessing in June 1985.

It had taken some twenty five years to overcome the objections which had been led by the Hertfordshire and Essex County Councils, Uttlesford and East Herts District Councils and several influential landowners. The objections had been based on economic, social, financial and environmental issues. Nevertheless, the BAA's case was finally accepted.

The challenge to Eastern Electricity was very clear. With this background in mind, it was necessary that proposals were carefully prepared in the knowledge that even after the decision for the go-ahead had been made, the anti-Stansted lobby would still raise its head.

The first indications were that the objectors would base their case on the statement of the Government Minister of the time:

"The Government does not intend to betray its obligations to an attractive part of the English countryside and will resist airport-related development outside the new airport boundary."

This raised fundamental problems for Eastern Electricity as an overhead line was part of a much wider development plan. It was recognised that the application was the first in an area which was within the new airport development. The local residents perceived the overhead lines as a forest of towers to be built on their doorstep.
It had to be demonstrated to the local planning authorities, the landowners, the environmentalists as well as local residents, that the proposals would have minimal impact on the local environment. It was at this point that the Department of Architecture at the University of Strathclyde was approached for assistance.

3.3. Computer Simulation

The University was already carrying out work on the development of computer programs for visual impact analysis comprising three-dimensional perspective viewing from any required viewpoint. These programs were used for large scale, terrain level modelling and appeared ideally suited to support planning submissions on the Stansted line.

Some of the earlier work at Strathclyde had been applied successfully to the planning and visual impact assessment of a double circuit CEGB 400 kV line. This included the production of computer projections of towers and lines superimposed onto a computer model of the terrain. Validation studies, conducted after this line had been built, demonstrated the high level of accuracy of the modelling techniques.

The aim of the Stansted project was to analyse the visual impact of two 33kV wood pole overhead lines by superimposing computer images of the planned line onto photographs of the routes; (these photographs would be taken from visually or emotionally critical viewpoints). The photomontages thus produced would give a true visual impact of the proposed line in terms that were readily understandable to both planners and public.

3.4. The Basic Data

The information the University required from Eastern Electricity was relatively straightforward:

a) A 1:10000 OS map of the Stansted Mountfitchet area.

b) The position of the lines of poles marked with pole positions to the nearest metre.

d) Conductor sags for 200 mm² ACSR.

e) A set of photographs, enlarged to approximately A3 and taken with a level camera and compass. The actual viewpoints were seen as critical and they were chosen and discussed with professional planners.

f) A table of correct viewing parameters. For the accuracy of computer photomontage it is essential to establish the accurate location of camera and target point. In addition, the camera height above ground, the focal length of the camera lens and enlarging factors from negatives to print, were also supplied.

3.5. Computer Modelling

The computer modelling study of the new overhead line and its route was carried out in six stages:

i) Terrain
A segment of the terrain (6.5 x 2.5) from Bishop's Stortford to Burton End was modelled on the computer.

The contours with 5 m height intervals were digitised from 1:10000 OS maps.

The digital terrain model (DTM) was then interpolated from the OS map contours at 50 m intervals.

A polygon mesh with 50 m grid intervals was used to represent site features. Perspectives were subsequently generated. This stage was used to eliminate poles which were partly hidden by landform.

ii) Poles
The modelling of two intermediate and angle poles was the first step taken, the variation in height of the poles (10 to 12m) being incorporated into the geometric data.

d) Conductor sags for 200 mm2 ACSR.

e) A set of photographs, enlarged to approximately A3 and taken with a level camera and compass. The actual viewpoints were seen as critical and they were chosen and discussed with professional planners.

f) A table of correct viewing parameters. For the accuracy of computer photomontage it is essential to establish the accurate location of camera and target point. In addition, the camera height above ground, the focal length of the camera lens and enlarging factors from negatives to print, were also supplied.

3.5. Computer Modelling

The computer modelling study of the new overhead line and its route was carried out in six stages:

i) Terrain
A segment of the terrain (6.5 x 2.5) from Bishop's Stortford to Burton End was modelled on the computer.

The contours with 5 m height intervals were digitised from 1:10000 OS maps.

The digital terrain model (DTM) was then interpolated from the OS map contours at 50 m intervals.

A polygon mesh with 50 m grid intervals was used to represent site features. Perspectives were subsequently generated. This stage was used to eliminate poles which were partly hidden by landform.

ii) Poles
The modelling of two intermediate and angle poles was the first step taken, the variation in height of the poles (10 to 12m) being incorporated into the geometric data.
iii) **Catenaries**
Overhead cable catenaries were modelled to give a more realistic representation of the proposed overhead line. The method adopted was to model catenaries in accordance with the distance from the camera, for each specified view. Most of the catenaries were single conductors and only those close to the observer were modelled on three separate conductors. An average sag of 1.5 m was used for all the spans.

iv) **Lines of Poles**
Two proposed lines were modelled, one with 57 poles and the other with 54. The two main types of poles were copied, sited and rotated along a vertical axis relative to the selected datum point to generate a view of the proposed lines. The cable catenaries were then added to the data files for each of the views.

v) **Computer Generated Perspectives**
A series of perspectives were generated from the six selected viewpoints. These contained landforms and lines of poles with catenaries and were used as working plots to establish the degree of clipping by a particular landform.

vi) **Computer Photomontage**
The computer photomontage technique was used as the most appropriate to communicate the visual information. Views were generated of pole lines which were then plotted onto the transparent overlays and then merged with the photographs.

### 3.6. Conclusion

The computer based visual impact analysis yielded a series of highly accurate and economical images (at a cost of £500/view) which could be readily appreciated by all the interested parties involved in the planning process.
The project was successful: planning permission, wayleaves and ministerial consents were granted on the basis of the images presented and the line has since been constructed.

4. The Cavia System

The comprehensive system for computer aided visual impact analysis developed by the ABACUS group in the Department of Architecture and Building Science at the University of Strathclyde is known as CAVIA.

The elements which comprise CAVIA are:

**VIM** is a utility which is used to create and manipulate 3-D objects, with the objective of producing visualisations for either VIEWER, VISTA or ROVE.

**DIGIT** is a utility for digitising 3-D objects.

**INSITE** and **SITE** are used to digitise ordinance survey contours and to create topography from contour data.

**ROADS** is software for the overlaying of roads onto the digital terrain model.

**TREE MODELLER** is a utility for parametric modelling of botanical trees. This software can simulate changes in growth patterns due to gravity and wind as well as the ageing process (i.e. changes over time) of individual trees.

**CAD BRIDGES** are utilities which support formats for integration and exchange of data; this facilitates the importation of data from other CAD systems.

**VWALK** is a utility for setting up view paths for animation. It is possible to explore interactively, a variety of viewpaths and then program a particular one for video recording.

**MOTION/SCRIPT GENERATOR** is a utility which defines the movement of the object in 3D space.

**VIEWER** is perspective viewing software which is used to visualise geometry in 3-D wireline, in stereo and with detail drop out.

**VISTA** is software for visualising topography and transmission lines in 3-D with fully coloured and shaded surfaces.

**DIM** is a utility for detailed numerical and visual simulation of artificial lighting. It is a 'first principles' multi-chromatic lighting simulation model.
capable of representing complex geometries and randomly distributed luminaires.

ROVE is an interactive 3-D animation package which takes geometry, colour and path files and produces the animated sequence which can be seen in real time on the computer screen or output directly to video.

ROVELT is a modification of ROVE which incorporates a simple lighting model.

ARTICULATION is a utility which employs object oriented system architecture which allows geometric bodies to be manipulated in 3D space using motion scripts.

ARTISAN is software for image mixing which allows for sophisticated image manipulation and composition (including foreground/background treatment), painting and special effects.

GAMMA FILTERS are utilities for modifying the gamma of images typically used in computer photomontage.

DEPICT is a utility for pre-processing of VIEWER picture files. The depth cueing routines are implemented in this module. The output takes the form of standard plot files or ASCII files which are then used in electronic image mixing.

5. Bibliography