Visualizing n-Dimensional Implications of Two-Dimensional Design Decisions

Stephen M. Ervin
Harvard University Graduate School of Design
Department of Landscape Architecture

Abstract
This paper describes several experiments in visualizing implications of landscape planning and design decisions using a combination of GIS, CAD and video animation technology. We use simple grid-cell GIS databases and site-scale polygonal models to provide visualizations of site planning design proposals and environmental impacts, with both static and animated images. Rather than pursuing 'photo-realistic' simulations, we are interested in how abstractions and representational conventions can be used to gauge visual and environmental impacts of proposals for landscape change, in a dynamic, interactive computer-aided design environment.

Introduction

This paper describes several experiments in visualizing implications of landscape planning and design decisions, using a combination of GIS, CAD and video animation technology in a heterogeneous computer network environment. Proposals for landscape change -- such as those related to new housing and infrastructure development, waste management or energy facilities, transportation corridors, forestry management and reforestation, etc. -- are initially represented and analyzed as two-dimensional grid-cell plans, using traditional raster GIS techniques. First-order evaluations of environmental impacts of proposed changes, implemented by models of varying degrees of complexity, can be represented as color-coded maps: red for danger, black for disaster, yellow for warning and green for acceptable, for example. In addition, the gross physical implications -- new masses of buildings, bodies of water, areas of pavement, clearings or new masses of vegetation, e.g. -- can be represented as simple polygonal models, scaled and shaped appropriately. These three representations: original plans, impact maps and three-d models -- provide data for a variety of modes of visualization. The three dimensional polygonal models can be 'walked through', using standard three-d modelling techniques, and viewed through 'color-coded glasses', seeing the landscape not in natural color, but in symbolic or evocative color, hence, with an added dimension of meaning. When these images are integrated or viewed over time, using simple animation techniques, we are up to five dimensions, and counting...

The close integration of GIS, CAD, video and other visualization systems is still in its infancy (cf Arc-CAD from ESRI and other similar systems), and both theoretical and mechanical problems remain in the way of satisfactory integration. This paper reports on one small effort to bridge the gap, and to bring the benefits of n-dimensional visualization together with the power of geographic analysis: a graduate landscape design studio concerned with siting and designing a new community, using a combination of raster GIS software ('macGIS' from the University of Oregon) and interactive polygonal surface software (the "POLYTRIMS" system from the University of Toronto Center for Landscape Research) in a heterogeneous network of computer workstations.

Geographic and Environmental Analysis

We use simple grid-cell GIS databases and site-scale polygonal models to provide visualizations of design proposals and environmental impacts with both static and animated images. In our second-year graduate landscape design curriculum, we teach two courses that introduce GIS approaches, and cartographic modelling, using simple Macintosh software ('macGIS' [5]), for site selection and evaluation. Students are given a database in the form of eight layers, or 'coverages', for two sites, on two disks in raster GIS format. Working with these base data, and following the framework of models described by Steinitz [8], the students develop a series of analytical 'process', 'attractiveness', 'vulnerability', and 'impact' models which guide their site selection and site plan evaluation process. Traditional cartographic analyses [1,9] yield site evaluations, sensitivity analyses and attractiveness and vulnerability models, based on a variety of criteria, from landscape ecological concerns to cost and visual preference. Typically there are about a dozen models which go into this evaluation -- "Soil Erosion Potential", "Groundwater Quality", "Cost of Construction", "MicroClimate and Energy Impacts" are examples of such models. This approach has proven useful for both teaching the logic of geographic analysis and introducing the complexity of large scale land use decisions [3]. In the last few years we have been exploring the explicit addition of visual analysis to this repertoire of models, as described below.

Based on some number of analytical models (but often in an 'intuitive' or 'personal' fashion), a preliminary site plan is developed by each student or team in the raster GIS
system, where each (approximately one acre) cell is assigned a new land use code – a simple two-digit integer code, modelled after the USGS land use categories but including more varieties of residential land uses, and possibly supplemented by special-purpose land uses developed within the context of the studio.

These preliminary land use plans are developed based on an initial analysis of the site using the analytical models mentioned above; the plans are then subjected to analysis by running them through more models which evaluate the impacts of the proposed development pattern. The plans are evaluated for gross impact using environmental impact models, which yield impact maps in the form of coded raster maps indicating impacts in five categories: 0= Not Applicable, 1=Compatible, 2=Minor Impact, 3=Major Impact, 4=Disaster, or 'Threshold' Impact. Then one (perhaps overly) simple quantitative analysis of any proposed site plan is the linear sum of the impacts over the proposed site plan area -- the lower the better. We stress the point that negative impacts are not necessarily 'Stop' signs, but are rather 'Warning' signs, which raise flags in areas of concern, and remind the designer to make special efforts to mitigate negative effects. Figure 1 shows a vulnerability map from one such analytical sequence.

**Figure 1. Vulnerability Assessment Map**

These vulnerability and impact assessments are informative and useful, but at a rather coarse level of aggregation. Furthermore, designers (and design students) are often frustrated at this stage by not having an 'image' of their proposed plan except in the most diagrammatic form. In addition, the possibility of studying motion through, around and of the site is important for many of these plans, as they are typically concerned with issues of public/private access and view. A standard visibility analysis in a GIS can (approximately) answer the question "Can you see the dump from the road?", but not "What might it look like?" -- much less "What will it look like".

**Visualization**

The simplest type of visualization is the GIS technique of 'draping', superimposing a pattern on a three-dimensional terrain. Figure 2 shows a typical site plan, 'draped' over terrain with roads and major streams superimposed, on a 3600 acre site. Each cell is colored according to its land use type, modified by a simple cosine shading to enhance to appearance of relief.

**Figure 2. Site plan draped over terrain**

In order to get at the question of "What might it look like?", at this preliminary stage, we have developed a set of symbols for three-dimensional representation: buildings and houses of varying densities and overall form, several types of vegetation, smokestacks and parking lots, for example. These symbols, corresponding to the land use codes, can be arrayed in three-dimensions, over a digital terrain model, to provide a preliminary 3-d analysis of the (possible) form of the proposed site plans. These views are understood to be approximations; more realistic than just plan views, but more diagrammatic than final renderings or presentation drawings. Figure 3 shows a sampling of some of these simple polygonal figures.

**Figure 3. Land Use 'Objects'**

(See color plates, p. CP-38.)
Working directly from the GIS raster files of the proposed plan, a translation program is used to generate 3-D polygonal surface files using a library of symbols to schematically illustrate a landscape of land uses with these simple objects (trees, houses, etc). These images were produced on a Macintosh using software developed by the author.

Figure 4 shows a composite perspective view of the center of one of the study sites produced on a Macintosh. In this view, the elevation data has been rendered as a triangulated underlay, colored by a map that combines land cover and hydrology. On top of this terrain, vegetation is represented by simple two-dimensional symbols produced with a slight random variation in size and shape; buildings, residential and municipal, by three-dimensional block figures. In this version colors are chosen for a somewhat 'realistic' approximation to natural phenomena (i.e., blues, greens, browns).

Using these simulations, judgments can be made at the preliminary design stage about dimensions and densities of view corridors, buffers, height limitations, vantage points and special views. In our present studio schedule, this preliminary review occurs at mid-semester, so students have the opportunity for two or more cycles of revision and re-evaluation using this technology before final plans are developed. Right now there are logistical complications that make the process more time-consuming and less transparent than we would like, but these are circumstances that will continue to change. While we don't presently get designers working directly on the IRIS (as Professor John Danahy does in his studios at Toronto [2]), we do anticipate a seamless and transparent integration of this visualization tool into the preliminary design process that will continue to rely on GIS. In this sense, the visual evaluation becomes just one more in a suite of evaluation models used to inform the design and planning process. One use of this set of techniques is to begin to appreciate change over time, using color cues along with animation. Figure 6 shows four frames of views of the same terrain as in figure 4, but set in the four seasons: summer, fall, winter, spring. In each case, the underlying data model has not changed, only the viewing parameters have. That is, different symbols have been substituted as appropriate (bare branched deciduous trees in the winter, e.g.) and color palettes have been changed (fields, for example, are white in winter, bright green in spring, medium green in summer, and tan in the fall.) These visualizations are the most 'life-like' in their intent, as they give a feeling of different aspects of the landscape at different times of year. Other dimensions of the landscape - such as visibility distances, or sun/shade pockets, 'sense of enclosure' or 'view of water', also change with the seasons, and these analyses can be overlaid on the substrate of the colored landscape to add to the visualization of the landscape character in many of its dimensions.

(See color plates, p. CP-38.)
analysis one step further, providing a way of viewing proposed changes in the context of their impacts. We dimensional landscape. Thus for Good, yellow for Neutral -- colored landscapes, using the color code for impacts as red, green, whereas -- likewise for other features, such as water bodies and structures. This approach -- wearing virtual 'rose-colored glasses' -- is simple but effective. Patterns of impacts that have an element of geographic or spatial correlation (such as along drainage courses, or ridgetops, for example) are glaringly obvious in this approach, and seem much more immediate when seen in pseudo-three-dimensions than when simply presented as a colored impact map.

Similarly, we can animate motion through these false-colored landscapes, using the speed and graphic power of the IRIS computers, and the interface developed for the CLRView program. Walking from the green forest into the red housing and parking area, or taking a drive along a road and watching the hilltops along the road to see if the highly impacted landscape is visible in red, are both more personal and engaging than simply seeing a viewshed response to visual images.

This is not to say that the three-dimensional substrate so created could not be used as the basis for more finished renderings -- only that we do not at present use them this way. Questions about design processes -- "When are what graphic products produced, and for whom?", for example -- are raised, but not answered, by our efforts.

Whereas the environmental sensitivity and impact models described above may be defensible (7), by virtue of being reproducible and articulate (although this does not imply that they are necessarily correct!), individual responses to visual images are neither so reproducible nor so articulate. We believe that these kinds of visualizations are important component of any public debate about land use plans and impacts, with the caveat that the public may not be so ready to make the distinction between "might look like" and "will look like". There is a tendency for non-designers to take graphic products literally, rather than suggestively; this is a major disadvantage of this technique outside of designers' private investigations. For designers and other professionals who are more sophisticated (and hence critical, in the best sense) about graphic products and design processes, we are adding one more element into a rich and complex soup of models and abstractions (10) about the world being designed and explored. This idea, of multiple views of evolving models, is the best underpinning for comprehensive computer-aided design, whether it's called CAD or GIS (or anything else...). This work may be seen as following along the lines of the 'virtual reality' movement, but we would stress that there is no single reality. Rather, there are many dimensions to which are best supported by CAD systems with their fine resolution and capacity for detailed geometry, etc.

Designers naturally work back and forth between these scales, and, to some extent, between these computer media.

The images produced are rough in many ways: all trees and buildings are alike and rather diagrammatic; colors are shaded but there is no provision for the subtleties of texture or curved surfaces; the ground is broken up into colored triangles -- but nonetheless these simulations are remarkably informative and useful. This methodology linking planning scale analysis with site-scale three-and four-dimensional simulations offers promise for GIS-CADD integration, and animation [6].

We stress that the visualizations so produced are attempts to answer the question "What might it look like", rather than "What will it look like?" So we are not quite treading the murky waters of 'photo-realistic' visual simulation, with its technical complications (ray-tracing, surface texture mapping, shadow casting and all...), and its deep-seated theoretical problems (who says what constitutes realism, anyway?). Instead, we are producing the equivalent of a designer's quick thumbnail sketch, cross-section or doodle. This has undeniable value in the design process, but no overly great weight is placed upon it: these images are ephemeral and mutable at will -- designed for change and recycling, rather than as finished renderings.

Conclusions

Rather than pursuing 'photo-realistic' simulations, we are interested in how abstractions and representational conventions can be used to gauge visual and environmental impacts in a dynamic, interactive computer-aided design environment.

Computer programs for manipulating geographic information (GIS) provide powerful tools for addressing landscape design and planning problems, but typically handle data that are too coarse for three dimensional site-scale design. Regional landscape planning and urban design require higher levels of abstraction, and larger scope (smaller scale) decisions, than do site-scale project designs.

(See color plates, p. CP-38.)
any proposed reality, that are selectively explored and ignored in design and evaluation processes. We want to develop control over these dimensions, so that the design and evaluation processes can be as rich as the designers imagination and the realities of the situation warrant.

We imagine (and are undertaking) a number of improvements and refinements to our present system. They range from faster IRISes that can support real-time integration of two-dimensional raster layout, impact analysis and visualization along with three-dimensional renderings -- thereby eliminating the intermediate translation step -- to constraint-based models that enable 'working backwards', designing directly in three-dimensions and producing impact analyses directly, or, entering a desired impact map and generating an appropriate design to suit!. Interface questions, not surprisingly, begin to be significant when interactive design processes are envisioned, and questions of screen layout, response time, visual cues, and others all become more than just academic. We have several on-going investigations looking at interface aspects of the system, and expect slow convergence on a flexible, workable, multi-windowed and multi-abstraction-level environment for exploring land use plans and environmental impacts.

Acknowledgments

Thanks to my colleague Carl Steinitz, principal developer and instructor of the courses described herein; Caroline Westort for assistance in preparation of graphics; the University of Toronto Centre for Landscape Research for productive collaboration; Apple Macintosh Allegro Common LISP for a wonderful software development environment; and the Harvard University Milton Fund for support

References


