Designing with Maps: Integrating GIS and CAD

by Stephen M Ervin
servin@gsd.harvard.edu

Abstract

This article discusses and illustrates the convergence of 'GIS' and 'CAD' technologies, especially from the point of view of landscape architecture and planning.

Introduction

As 'CAD' and 'GIS' software have evolved and specialized over the last three decades, they have seemed to be quite distinct in their theoretical basis and practical applications; 'CAD' for working drawings and landscape design, GIS for maps and landscape planning. However correct this (mis)conception was in the past, however, in the future our conception and use of GIS, CAD and other digital information processing techniques will have to change, along with their successful integration and evolution into new tools for representing and exploring landscape phenomena -- visual, ecological, political, and others.

Conventionally, geographic information systems may be divided into two kinds: those based upon 'raster' data (two-dimensional arrays of data values) , such as those generated by satellites and other remote sensing operations; and thoses based on 'vector' data (lines and polygons). Raster data, while they often resemble photographs from a sufficient distance, are usually overly abstract and simplified when viewed close-up, and so have long been considered only suitable for use at the 'regional planning' end of the spectrum. (See Figure 1.) Grid cells, or pixels, are often as much as 1 acre in size; although current satellite technology can generate finer resolutions such as pixels 20 or 30 meters square. Vector data, while offering more detail and the potential to 'zoom in' without loss of detail, as with a typical CAD system, have been considered to be too cumbersome for very large areas, and so most useful at the 'fine scale design' end (see Figure 2.) This differentiation between the technologies has led to a further widening of the perceived distance between the two ends of the planning and design spectrum.

Today, these differences are less compelling than they once were. New developments in computer hardware and software have all but eradicated the distinction between 'GIS' and 'CAD' software on the one hand, and 'planning' and 'design' data on the other hand. The ready availability of digital data at all scales, reliable vector-to-raster conversion techniques, and increasing compatibilities between software products and hardware platforms makes the integration of GIS, CAD and other information and communications technologies (such as video and multimedia) not just possible, but imperative, for landscape architects. In this digital era, spatial information systems are as necessary as telephones and fax machines or shovels and survey tools.

Examples

The following illustrations offer a small sampling of some of the possibilities for integration opened up by the current state of GIS and CAD software. They are not represented as conclusive nor exemplary, but are intended to be illustrative and provocative.

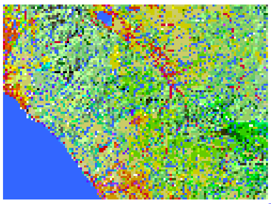
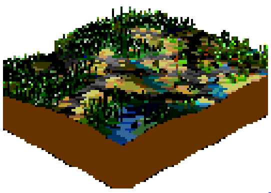
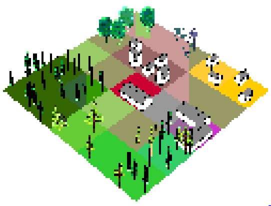
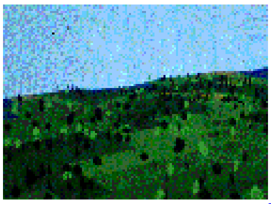
 Figure 1. shows a typical 2D GIS map: a map of land use and land cover over a region of Southwest California, between the metropolitan areas of Los Angeles and San Diego, created for the purposes of evaluating risks to biodiversity posed by rapidly expanding residential development in the area. These data were acquired through a time-consuming process of collecting and collating digital information from a variety of sources, public and private, in a variety of forms. (But all the data were already in digital form; effort which would once have been spent on field surveying and photographic interpretation was spent instead on digital data combination.) Data such as these serve as the basis for ecological modelling of landscape processes, such as hydrological dynamics, habitat for single or multiple species, and vegetation change over time. Landsacpe architcets and planners have always made local design decisions in the context of broader environmental conditions and impact evaluations. Now the GIS (planning) map can be directly imported as a data layer, or background, into the CAD (design) system.

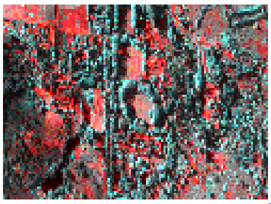
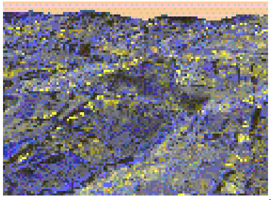
 Figure 2. shows a computer generated view inside a 'virtual model', in a 3D CAD system, of a proposed urban landscape (a proposed new campus, not in the same landscape as in Figure 1., although it might have been.) Polygonal modelling tools are used to create a landform and buildings out of flat triangles; these are combined with 'texture-mapped' trees and people to create a collage of convincing realism. The data underlying this model are embedded within land use data such as in the previous figure, but the eye-level view is set inside the model for this perspective view. In such a computational design environment, siting of buildings is informed not only by three-dimensional massing considerations, but by contextual information such as zoning and adjacent land uses.

 Figure 3 shows a computer model of an area of imaginary landscape in-between 'site' and 'regional' scale, created by automatically converting a two-dimensional raster GIS map into a three-dimensional 'CAD-based' landscape rendering. Integration by manual combination of data, or importing and exporting files between programs is one useful form; but automatic translation between CAD and GIS formats is also possible. A pre-defined library of three-dimensional forms and textures corresponding to landscape types -- houses, farms, fields, forests, etc. -- forms the basis for the rendered CAD model.

 Figure 4. shows one such library of 3-D landscape 'objects' (created in an experimental computer system by the author, but similar to pre-defined symbols in any CAD system's symol library). In maps and models like these, the symbolism and coloration used need not be limited to conventional or 'realistic' representations. Instead, the results of various landscape analyses are used to portray landscape conditions, sensitivities, vulnerabilities and opportunities in different colors and shapes, thereby highlighting the fact that a given landscape has many different interpretations, depending upon the viewpoint and biases of the viewer. The developer's view and the conservationists' view, for example, are

not always congruent; knowing where the greatest conflicts (as well agreements) are located can greatly help in some of the conflict-resolution aspects of landscape planning and design.

 Figure 5 and  Figure 6 show two more views of a landscape created in this way (automatically generating three-dimensional objects from two dimensional data maps, this time on a different computer system). The first is an aerial perspective, the second an eye-level view. Both are highly stylized and simplified, but both combine the accuracy and objectivity of geographic data sources with the visual appearance of a 'virtual' landscape. (Figure 6 also illustrates the potential for image-precessing cut-and-paste technology, as well.) For designers, both aerial and eye-level views are important, as are both scientifc and visual evaluations of any landscape under consideration.

 Figure 7 and  Figure 8 show a landscape re-created on a computer by the use of sophisticated remote sensing and image processing techniques. The original data were from a very-high-resolution scanner mounted on an aircraft flying at low altitude over the slopes of Mt. Kenya, Africa. The sensor initially recorded a variety of spectral readings, which were converted in a computer into colors and textures, and then 'draped' over a three-dimensional surface model. While these data are two-dimensional raster in their original form, the resolution is sufficiently high (one pixel is about one meter square on the ground) that the resultant image has a 'photographic' quality, and a level of detail traditionally associated with 'CAD', rather than 'GIS'. Figure 7 shows the original raster data, classified into several categories representing vegetation and crop types; figure 8 is a perspective view of those data over a digital terrain model. The three-dimensioanl digital terrain model was automatically generated by ortho-rectification of a stereo pair of images, and could now be fed into a CAD system for detailed design. The false coloration of these images is used for the purpose of classifying and evaluating landscape types from an agro-forestry point of view; the same images could be used as background for new settlement or agricultural design projects. This high-resolution data is similar in format, and potential uses, to the 'Digital Ortho-Photo Quads' (DOPQ's) now being distributed by the US Geologicval Survey as part of the National Information Infrastructure.

Conclusions

Designers have always been engaged in making models and other representations of proposed changes, and of existing conditions before the changes. A conventional view has been that GIS models are usually best suited to (large area) existing conditions, and CAD systems best used for (smaller area) proposals. But there is no compelling reason for this to continue to be so.

Computer aided design systems already demand new ways of working, compared to their traditional paper and ink analog counterparts, because of several fundamental differences in representation. Scale-less three-dimensional models (or models always at 1:1 'full-scale') which can be maintained over virtually any spatial extent, and then printed or displayed at selected scales (1:00, 1:10000, etc.) offer quite different possibilities than do fixed-scale two-dimensional paper drawings. Similarly, geographic information systems, which enable multiple layers of information to be overlaid and manipulated simultaneously, and again re-projected into any desired scale or projection system for hard-copy output, are quite different than USGS maps as fixed scale, resolution and information content.

The combination of complex, multi-dimensional digital models with fast computers, high capacity storage devices, telecommunications, and such devices as GPS satellites, multispectral scanners and immersive display systems offers landscape architects a host of new ways to model and explore landscapes. Even if the full promise of 'virtual reality' is still a considerable way off in the distance for designers, the ability to design with maps in ways never before imagined, is quite exciting enough.

Web Notes

For some other work on landscape visualization and the integration of CAD and GIS, see:

- "3D for FREE" article @ http://www.clr.toronto.edu:1080/LINKS/GISW/origarticle.html
- "Integrating GIS and CAD to Visualize Landscape Change" @ http://www.fes.uwaterloo.ca/u/kmayall/Research/
- GIS World May 95 issue on GIS/CAD integration @ http://www.gisworld.com/mag/gw/may/may.html
- Visualization of Digital Terrain Models @ http://www.tel-irrs.mi.cnr.it/DTM.html

(P.S. to visitors: If you know of other important/interesting/appropriate links that belong here, please contact me . Thanks!)

Notes:

Figure 1. The 'Study of Alternative Futures for Camp Pendleton in the Maintenance of Biodiversity', sponsored by the United States BioDiversity Research Consortium and the Strategic Environmental Research and Development Program, is currently being undertaken by researchers at the Harvard University Graduate School of Design and Utah State University. For more information, visit: http://www.gsd.harvard.edu/epa/EPA.html. Map produced using Arc/Info software by ESRI on a SUN computer.

Figures 3 and 4. Created on a Macintosh computer using software written and developed by the author. Contact: servin@gsd.harvard.edu

Figure 2, 5 and 6. Created by graduate students in landscape architecture at the Harvard University Graduate School of Design. Graphics created using the POLYTRIMS/CLRVIEW computer program developed at the Center for Landscape Research, University of Toronto, Canada, on Silicon Graphics computer. For more information, visit http://www.clr.toronto.edu:1080/clr.html See also the article: '3D for Free', by Rodney Hoinkes and Eckart Lange in GIS WORLD, July 1995.

Figure 7 and 8. Created by doctoral student Douglas Olson, at the Graduate School of Design, using Imagine software, by ERDAS, Inc. on SUN computer. Contact: gsd94jdo@gsd.harvard.edu

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About the author: Stephen M. Ervin, Associate Professor in the Department of Landscape Architecture, Graduate School of Design, Harvard University teaches and conducts research in the areas of design, computing, media and technology, including Geographic Information Systems, Computer Aided Design, Image Processing and their intersection. He has taught and lectured worldwide and published articles in a number of journals including Process Architecture, GIS World, Landscape Architecture Magazine, Computers, Environment and Urban Systems, Computer Graphics and Applications, and others The founding chairman of the American Society of Landscape Architects' Open Committee on Computers in Landscape Architecture, he holds a Master's degree in Landscape Architecture from the University of Massachusetts at Amherst and a PhD in Urban Studies from the Massachusetts Institute of Technology.