Inter-related Scaled Models of the Built and Natural Environment:

Merging CAD with Satellite Image Viewing

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By inter-relating CAD and satellite image earth-viewing tools at building specific, city-wide and larger global scales, a wider framework of observation yields insight into the connectedness between built environments and tracking influences between them. The technologies for visualization and analysis at distinct scales are moving towards greater integration. This project demonstrates integration through three case studies, each at a different scale of application, and considers performance issues and implications for more general use.

More specifically, CAD, GIS and now Satellite Image Based Earth Viewing systems all have found separate application within Architecture, Urban Planning and Strategic Regional Analysis This paper reports on an effort to test the tighter coupling of these systems on three projects, each at a different scale: (1) urban and regional scale, (2) continental scale, and (3) hemispheric analysis scale.

Keywords: CAD, Earth Viewer, Digital Terrain Model, Comprehensive Plan, Architectural Review Board, Computer Animation

Introduction

This effort to integrate an earth viewing system with CAD was examined in three case studies: (1) a city modeling project funded by a municipal planning authority, (2) the digital reconstruction of an expeditionary trail across a continent, and (3) the hemispheric relating of a historic colonial settlement in the so-called “Atlantic World back to its origins. When merged with CAD, the earth viewing system created a wider area context for understanding the built environment.

The integration of earth-viewing systems and CAD is presently under early development by a number of commercial vendors. However, stronger links at present exist between earth-viewing systems and GIS. For example ESRI links a global viewing systems tied with GIS in new product titled Globe-Explorer. The system is capable of placing relatively simple polygon data into the context of a global viewing system. Links between CAD and GIS are also fairly well established in architecture and planning practice through data exchange techniques and overlay methods. For example, the partnership
announced by Bentley Systems and ESRI in North America, provides for a tighter exchange of basic 2D and 3D polygons between CAD and GIS, such as in the shp file format. Yet, it would appear that a stronger basis for design consideration might be obtainable by linking together an earth viewing system with the articulated 3D geometries of CAD.

According to one recent review, European based efforts have taken a lead in the relative integration of CAD and GIS (Ospina, July 2004). Notable among these products are CityGRID Planner by GEODATA as demonstrated at ECAADE in 2003. A laser scanner mounted on a truck produces a data cloud of surrounding building elevations in a relatively quick time frame. The resulting data can be integrated into a GIS or CAD based viewing system. Similar methods have been explored with photogrammetry or with laser scanning and photogrammetry combined, such as in the digital Roman Forum project at UCLA (Frischer, B. et al., 2000). Still, such systems seem more efficiently adapted to urban area analysis where buildings are located within relatively dense clusters and where the scanning system can take in a great number of building elevations in a single area.

A greater difficulty exists where buildings may be dispersed over longer distances, in some cases isolated on less accessible terrain and not grouped together. To scan all such buildings within a mixed rural and urban area is impractical due to time limitations and perhaps the lack of clear visual access from the ground, such as with respect to a building that may be located in on forested hillside estate away from a city center. Another concern is where the framework of analysis may need to rapidly shift from local to regional and perhaps state or continental wide frames in order to grasp the scope of influences over the built-environment. For such situations, satellite based earth viewing systems can already be integrated with GIS data on a wide area basis. However, in addition to satellite earth-view systems and GIS, the third leg of a more complete platform for viewing such data is the integration of CAD.

In the first example, a 3D regional building model is placed into the context of a large area watershed terrain model. In the second example, contrasting two mountain ranges and rivers that lie in separate parts of a continent provides an immediate sense of their differences in scale and surrounding context. In the third example, visually connecting a colonial city on one side of an ocean’s edge to the mother country on the opposite side helps to establish a relevant context for the materials and shapes of its buildings.

City Modeling Project

The city modeling project explored the urban and regional setting of Charlottesville, Virginia supported in part by a grant from the City Planning Department. The City has a historic central core that is continually the subject of new development. An architectural review board protects historic zones in the city. The modeling project is intended to set into place a tool for design reviews of new development proposals. An additional factor is that the City was recently ranked as a best place to live in the US and Canada according to one highly publicized national survey (Frommers, 2004). This ranking has put additional pressure on growth. There are at times conflicts between construction of new buildings and retaining the human scaled qualities and historical context of the city’s core.

In order to limit the amount of open urban space lost to infill development, new building construction can be displaced into the county or can occur in town by relaxing building height restrictions in some designated areas. Yet, these approaches might deprive the city center of its intimate spatial quality or diminish open space in the surrounding rural areas that make the region a desirable place to live.

One of the problems in building a city model was to ensure a broad level of generality mixed with location specific details. A highly detailed computer model at this scale is expensive in its allocation of disk space and real-time rendering performance.
Moreover, for broad-scaled visualization purposes, details aren’t needed except for specific instances of streetscape analysis. Therefore, the visualization project uses detailed three-dimensional models in some corridors of greater interest and combines them with less detailed massing models of other areas. While experimental tiling systems in CAD may help to alleviate problems with large-scale models, there are still tradeoffs to be considered with respect to the number of details depicted and the efficiency of the model. Therefore, limiting the size of the model is still useful.

On the one hand, the earth viewing system is a limited resolution terrain model that may be overlaid with aerial photos and building data. On the other hand, a CAD city model contains detailed three-dimensional building information focused on issues typically confronted during building specific architectural reviews. Blending these two technologies together is intended to give breadth and depth where needed.

In the following figure, a point of interest is the approach to the city from some low mountains to the east as depicted in the foreground. The higher Blue Ridge maintains are to the west of the city and are depicted in the background. To appreciate the larger landforms in this part of the Virginia Piedmont, it is helpful to view the entire terrain from a regional visual perspective. Therefore, a series of views are animated within the satellite image based viewing system. A larger regional view transitions to a large scale view of the central city. The large scale view of the central city then transitions to a specific part of the city. There’s a sense within this sequence that development within the city and the county is nestled within and limited in growth by the natural barriers of the east and west mountains.

Other cities along the Blue Ridge have surpassed Charlottesville in terms of allowable building heights.
and have already established somewhat less intimate character. Here, through satellite viewing, there is an opportunity to appreciate the larger sense of urban form that the newly relaxed height restrictions will allow. All the buildings in the county are captured in a 3D model draped over the satellite imaging system terrain model. Further, through a short macro program tied to CAD, each building’s height is extended to the maximum permitted as per the zoning area it is located in (e.g., industrial, residential, business, etc.). When observed from within a countywide visual perspective, the new relaxed height regulations don’t appear to disrupt the sense of open space in the region.

Yet, when the earth-viewing system is used to review the pattern of regional building construction in plan, some growth issues become more apparent. Whereas the region’s Comprehensive Plan anticipates density of new building construction in a few emerging so-called town centers, the entrepreneurial real estate market seems to accelerate rates of growth elsewhere. The true pattern of regional building construction, a checkerboard mix of pastoral foothills and upscale residential developments, is made visible through earth-viewing imaging combined with an overlay of a 3D massing model for all the structures in the county.\(^1\) New town centers appear to be emerging that are not in the Comprehensive Plan. The Comprehensive Plan therefore seems out of sync with the contemporary real estate boom under which the open space of the region appears to be disappearing.

At a more detailed level of evaluation, the city’s recently increased building height allowance of 100 feet may be re-considered. A densification of the city center would have some obvious benefits of reducing development encroaching upon open space in the surrounding county, assisting the tax base, and creating a greater mandate for mass transit. However, as one approaches the downtown core of the city, an intimately scaled streetscape is maintained by predominantly two-story building structures. This more articulated CAD model reveals the architectural style of the city and makes clear the historical context against which the relaxing of height constraints would seem to pose a challenge.

**Continental Scale Project**

The year 2004 is the four hundred year anniversary of a nationally celebrated expedition of Meriwether Lewis and William Clark, two Virginians who attempted to find a water route to the west coast of the North American continent. The expedition was not the first contact between Euro and Native Americans in the western part of the United States, but figures importantly in the perception of the relatively

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unknown west in the newly established nation. The expedition brought back many descriptions of the differences between eastern and western mountain ranges and spaces. The differences between the smaller scaled spaces of the east and the larger scaled spaces of the west can be visualized through techniques that combine earth viewer low resolution terrain models with more detailed CAD based digital terrain models. Through a combination of low resolution earth viewer images and more detailed digital terrain models, several critical points along the route from east to west were contrasted in depth.

The eastern origins and mindset of Lewis and Clark are perhaps rooted in the relatively smaller scaled Appalachian Mountains and Shenandoah Valley of their native Virginia. The scale of the Appalachian Mountains may be best represented by the Cumberland Gap in North Carolina, the point of passage for several historical expeditions westward. On the other hand, the more dramatic mountains of the west are characterized by a point in the Rockies known as Lehmi Pass, which the explorers crossed in their journey west. Similar pairings of differently scaled spaces east and west occur in comparing the Falls of the Ohio River with the Great Falls of the Missouri River. In their final approach to the Pacific Ocean, the Columbia Gorge posed yet a different river condition that can be contrasted with the Ohio and the Missouri.

Earth viewing tours were integrated with more in-depth digital terrain models of the specific sites mentioned above, and then placed within a greater continental context. These inter-related scales suggest the radically changing character of the land from east to west. A continuous animation sequence juxtaposes the physical contrasts between these different settings. Moreover, overlaid with draped satellite images of contemporary development, such as at the Great Falls of the Missouri, we can sense how much the land may have changed from the expedition’s time frame.

Draped photography techniques are also used to examine Clark’s map against the actual course of the Missouri river at the Great Falls, one of the more significant points in the expedition’s journey west. But for a few discrepancies along some bends in the river, his map has remarkable accuracy given the technical means and opportunity for making such measurements at the time.

**Inter-Continental Scale Project**

The year 2007 is the four hundred year anniversary of Jamestown, the first permanent English settlement on the North American Continent. Jamestown is one of a series of colonial cities that led to the establishment of more permanent European colonial communities in North America, South America, and Africa. Historians and archeologists who share an interest in the emergence of these settlements have identified their topic as “The Atlantic World“. A digital reconstruction of Jamestown and its relationship to the Atlantic World is the basis for a larger scaled inter-continental application of an earth viewing system in conjunction with CAD and digital terrain modeling.

Through earth viewing mixed with CAD, we can begin to trace where localized building traditions in England may be related to construction in North America. The Jamestown Digital Reconstruction project explores the archeology of Jamestown.

**Figure 5**

*Views of Lehmi Pass and Cumberland Gap in Earth Viewer and Sectional Comparisons*
within this greater context. From a hemispheric point of view, Jamestown, Virginia may be more closely linked to Lincolnshire, England than perhaps to nearby French influenced New Orleans. Similarly, Spain may have a closer connection to the new world cities of Albuquerque and Santa Fe than either city may have to Jamestown. This pattern can be noted without the aid of an earth viewing system, but a sense of the distances involved and overall context would be more difficult to appreciate. For this project, an earth viewer based animation begins in London, the point of departure for Captain John Smith. It loosely tracks his voyage that led to the settlement of Jamestown. The animation tracks a pathway through the Azores, The West Indies, and the Mouth of the James River to Jamestown. Through animation it is evident that the Azores and the West Indies serve as important land based links across the Atlantic due to their relatively close proximity to each other. Towards the end of the animation, overlaid onto the earth satellite viewing system is a computer model of a thatched roof structure that archeologists at Jamestown have traced backed to Lincolnshire, England. Also overlaid onto the earth viewing system, we see a detailed 3D preliminary reconstruction of Jamestown’s statehouse that derives its shape from precedents in England, figure 9. A more complete connection between exact precedents on identifiable buildings remains as the basis of further work. Cities that have similar characteristics in street layout can also potentially also be visually connected on a large earth-scale. Seeing the pattern of such cities on a hemispheric scale may provide a context for historical design analysis. Given the difficulty of simultaneously seeing the patterns of two cities directly on a zoomed out model of the earth, however, the application of an earth viewing system in tracing architectural and planning influences between continents is not without difficulty.

General Observations
The complete integration of articulated three-dimensional building geometry of CAD into the earth viewing systems is still not fully in place. The massive regional construction building models obtained in these studies were developed writing case specific computer programs that facilitated specific 3D renderings in CAD. The renderings, not the direct three-dimensional geometry in CAD, were then geo-referenced into the earth viewing system. At the present time, earth viewing systems provided by ESRI and Keyhole can handle the import of simple polygons from CAD. The direct integration of more complex three-dimensional geometry seems but a few steps away. The author is working towards a more integrated functionality. At the local and regional scale, the earth viewing system can immediately relate existing patterns of

Figure 6
View of Columbia Gorge and Great Falls of the Missouri in earth viewer (above) and in CAD (below)

Figure 7
View of Great Falls of the Missouri
development to the intentions of zoning and building codes. At the continental scale, the earth viewing system can help to characterize different terrains and the transition between them over large land areas. At the hemispheric scale, an earth viewing system may allow us to trace architectural connections between cities that have a historical relationship.

Yet, not all aspects of the built environment are so easily inter-related. By making global wide visual connections in one animated sequence between continents at earth-scale, there is a risk of oversimplifying differences in land formations and building construction. By juxtaposing land formations at a continental scale, there is a risk of superficially relating places to each other that are more completely understood first hand. Finally, by generalizing architectural attributes within a regional-scale massing model of building structures, there is a risk of overly

Figure 8
Views of Statehouse over earth viewing terrain (top) and from more traditional CAD Photo montage (bottom)
homogenous characterization.
From these case studies, it seems that inter-relating scales is best understood as a way to abstractly associate relevant geometrical and spatial information for design practice, where the analytical methods may provide a coherent view between local, regional and more extended scales. Working with this technology affords an insight into the earth as one connected surface in a way that leads to speculation on what design issues may be inter-related over great distances. At the same time, the danger of viewing earth as a series of inter-connected spaces lumped into one model is that we abstract away the location specific qualities that may significantly alter our perceptions of individual places.

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Footnote

1. The overlay of CAD data into the earth viewing system was initially done with .shp data. At the present time, this is limited to 2D polygons. Therefore, the massive 3D model for the county was developed with macros written for Microstation and the renderings specifically related to and geo-referenced in the Keyhole system. This is a temporary technique that should be alleviated by working more directly with an earth viewer’s geometry database, an essential approach intended for future work.

References

Frommer’s Cities 2004 Ranked and Rated has named Charlottesville the Best Place to Live in America, 2004. The rankings were released in the
USA Today newspaper and on The Today Show on NBC.