A 3D Scrapbook Approach to Geospatial Analysis

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1. Introduction

We physically relate to our environment in three dimensions. However, familiar modes of interaction reside in 2D, which mimic our interactions with traditional paper-based media. In this work, our aim is to combine the situational understanding that can be gained from 3D GIS, with familiar paper-based interaction. Our system situates 3D terrains within a metaphor of a 2D interactive scrapbook or journal. This allows the geospatial professional to maintain 3D records of their analysis over time and perform calculations directly over extracted terrain regions. In addition, the system would be useful as a teaching aid imparting an understanding of the third dimension.

2. Related Work

A number of systems have explored the third dimension including Terrafly (Rishe et al., 1999), GeoZui3D (Ware et al., 2001) and ArcGIS (ESRI, 2006), amongst others. This typically takes the form of 2.5D height fields. However, a review by Stota and Zlatanova (2003) examined the present state of 3D GIS, which came to the conclusion that 3D GIS is merely at a stage where 2D GIS was several years ago. The review noted that in some cases 3D is simply used for graphic illustrations or the rendering of computer generated fly-bys.

Recently, a hybrid approach has been developed that combines 2D and 3D elements into a unified interface (Brooks and Whalley, 2007). This system allows multiple layers of information to be continuously raised or lowered by the user, directly over the base-terrain. During elevation, the layers morph between a 3D terrain and a flattened 2D map which helps mitigate issues of terrain and data occlusion in 3D. However, we argue that further possibilities should be explored that combine 2D interaction with 3D GIS.

3. Selection and Extraction of Terrain Regions

Our prototype allows the user to interactively extract and retain portions of the 2.5D terrain, which become incorporated into an editable journal. In order to proceed, the user must specify the regions that are to be extracted from the background terrain and subsequently embedded into the scrapbook. From the user's point of view the process is quite simple: the user specifies the location of a circular or rectangular region by directly clicking on a point on the 3D surface.

This is best understood visually. In Figure 1, there are two main areas with the scrapbook on the left and the background terrain on the right. At this stage the user has already clicked on a location on the background terrain and this area has become embedded into the scrapbook.

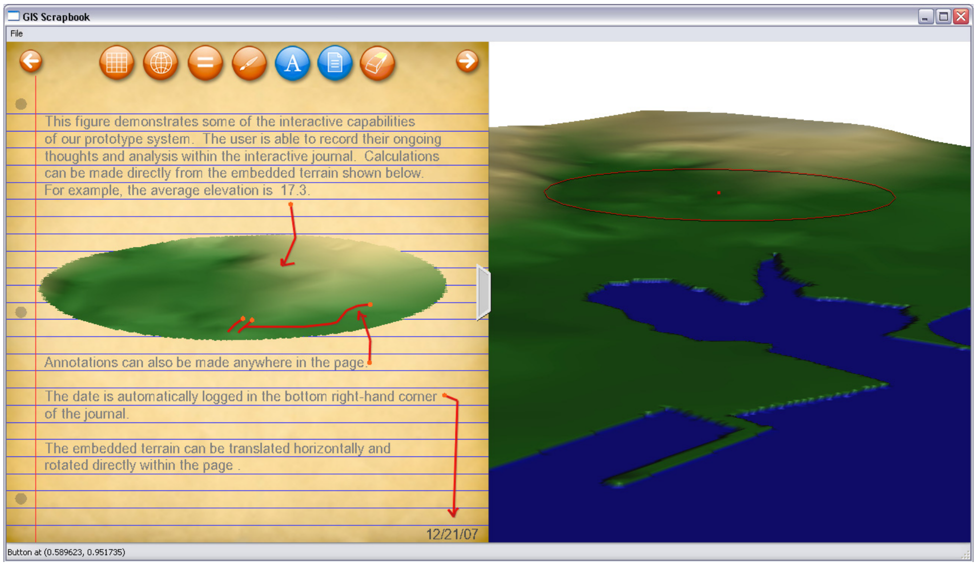

Figure 1: Journal interface with scrapbook partially occluding the 3D terrain on the left half of the screen. The scrapbook page incorporates an embedded terrain, annotations, written notes and computed equations.

However, when the user clicks on a point in the display window, this does not specify a single point in 3D space because of the scene's 3D depth. The user is in effect casting an imaginary ray that extends from the point on the display outwards into the 3D scene. From this, the system must determine which point on the ray intersects with the terrain surface, which is the location the user intended to pick. As the system is developed with the OpenGL rendering library, we utilize use the *gluUnproject* function which performs a reverse projection from the 2D display space to 3D. Using this function we can trace a mouse click from a point on the screen to the target 3D point on the terrain surface.

Moreover, the user may wish to specify any region on the terrain, and not just one that happens to be visible at present. This requires additional camera controls that allow the user to move to any location prior to specifying the selection region. These controls are typical of any virtual environment (using a combination of keyboard and mouse interaction), and so we will not discuss them in detail here.

4 Further Interactive Facilities

In addition to the primary function of extracting portions of the terrain, our system also provides a number of interactive features that support the recording of continuing analyses. These include facilities for modifying the embedded terrain region, as well as text entry and annotation.

Even after a region of the terrain has been placed in the scrapbook, the user retains some degree of interactive control over the embedded area. The user can continuously slide the center of the selected region to new locations by tracing the mouse over the surface of the 3D terrain, and the content of the embedded terrain updates in real-time to match. In addition, the selected region can be interactively rotated by dragging over the embedded terrain region itself, as shown in Figure 2.

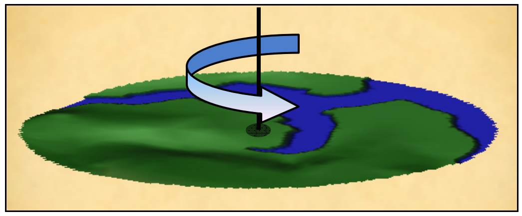

Figure 2: Interactive rotation of the embedded terrain region.

A drawback of the scrapbook interface is that it occupies half of the available screen space. To address this we have incorporated a simple hide/show control that slides the scrapbook away to the left side of the display. The control is shown in Figure 3 as a small grey handle on the right side of the scrapbook itself. The user simply clicks once on the control to hide the scrapbook, and again to reveal it.

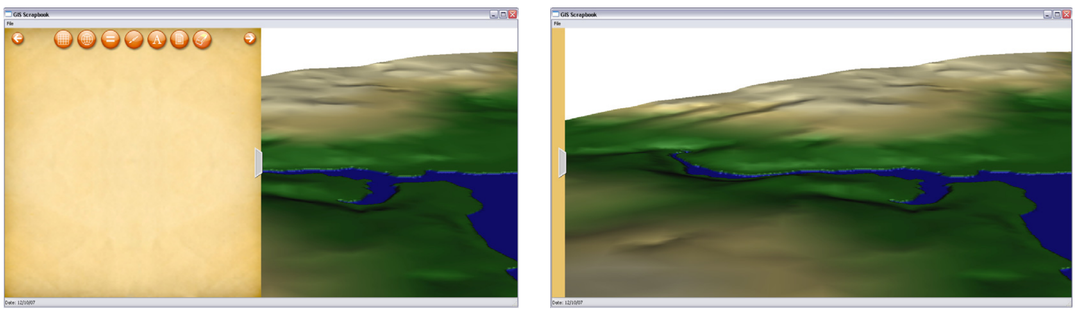

Figure 3: Scrapbook interface visible (left) and hidden away to the left (right).

Figure 4: Detail of interaction mode buttons.

The set of accessible buttons along the top of the scrapbook represent the remainder of the available functionality (Figure 4). The first two buttons on the left set the mode of terrain selection, for choosing rectangular and square regions respectively. This is followed by the equation button which inserts equations that operate over data contained in the extracted terrain area. The equation button presents an equation dialog, as seen in Figure 5. For example, if one inserts $AVE(\text{elevation})$ it will calculate and insert the average elevation of the embedded terrain region, at the current text entry point. As a proof of concept, at this stage we have only implemented a few example equations.

The remaining buttons represent modes of interaction that support note taking and annotation. The first draws free-form 2D scribbles anywhere within the scrapbook, including directly over the embedded terrain. The second enables text-entry mode, allowing the user to make detailed notes of their ongoing analysis. Following this is a button which turns paper lines on and off, which adds more or less visual structure to the journal page. Examples of each of these note taking functions can be seen in Figure 1. Finally, the eraser button allows the removal of annotations by tracing the mouse over each of them in turn.

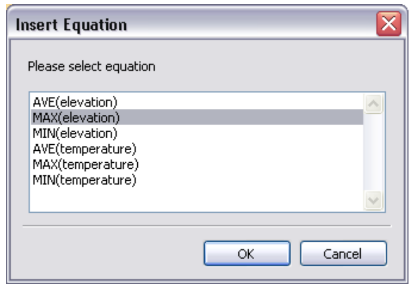

Figure 5: Equation insertion dialog.

5 Implementation Details

Both the 2D scrapbook and the 3D terrain are generated with the OpenGL rendering library using the C++ programming language. Currently, the texture for the 3D surface is algorithmically generated based on the local elevation, while the scrapbook is given a paper-like appearance by texturing a 2D polygon with a real parchment image.

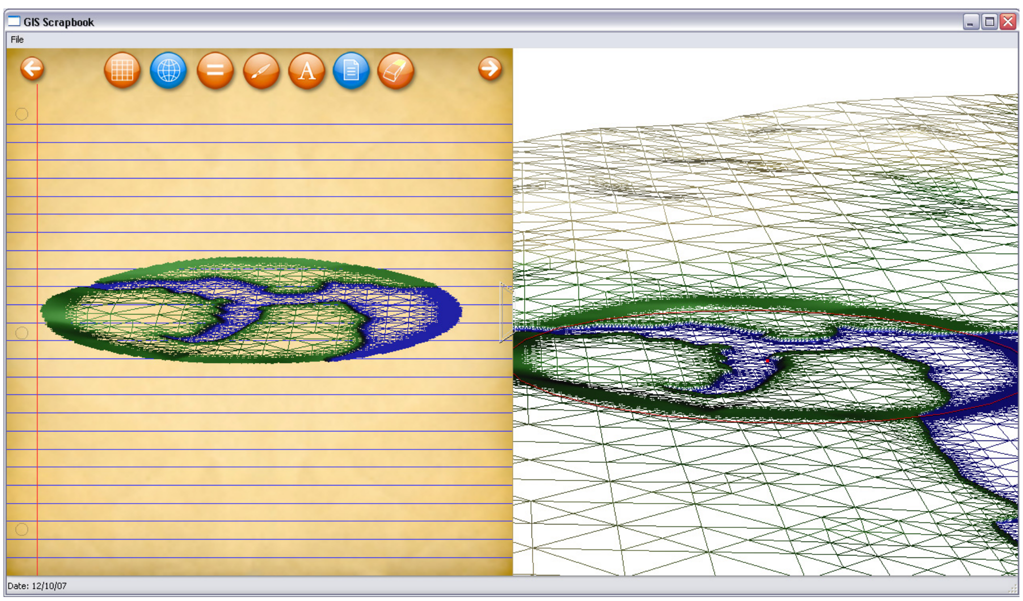

Figure 6: Wireframe rendering showing the non-uniform level-of-detail terrain.

We have constructed the geometry of the 3D terrain using a real-time adaptive hierarchical data structure (Wang et al, 2007), which allows us to increase frame rates without a significant loss of visual fidelity. This approach selectively adapts the number of polygons to the local topography. If the terrain's height is rapidly changing locally, more vertices are needed to accurately represent that local area. This can be seen in the wireframe rendering in Figure 6. An additional modification was required for the user selected regions. In order to produce crisp region boundaries, additional vertices are inserted around the border of a user selected region. Without this modification, the user selected regions would exhibit arbitrarily ragged boundaries, dependent on the changing precision of the local adaptive representation. The resulting selection region is shown as a wireframe rendering embedded within the scrapbook in Figure 6.

6. Conclusions and Future Work

In this paper we have presented a system that combines the situational awareness of 3D GIS, with familiar paper-based interaction. Our interactive scrapbook allows the user to save and analyse selected sub-regions of the 3D terrain, thereby maintaining 3D records of their analysis over time. However, the current system only prototypes the scrapbook concept, and there are many ways in which this work could be extended in order to increase its utility. Free form selection of embedded terrain areas (rather than circular or rectangular) would allow greater flexibility. We could also allow the user to modify the shape of the embedded selection region itself after it has been added. We would also like to significantly increase the range of equations that can be calculated over the embedded regions. In addition, it may be useful to offer facilities to add external images and diagrams into the scrapbook. Finally, thus far we have focused on the technical challenges of the system; we would also like to study the usability of the system.

7. Acknowledgements

This work was supported by NSERC and the Canadian Foundation for Innovation.

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Biographies

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