3-D Visualization for Civil Engineering Undergraduate Learning

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Introduction

Civil engineering analysis and modeling frequently reduces 3-D land features and structures to 2-D representations on such media as paper and overhead projection systems. Students often have trouble understanding the 3-D aspect of civil engineering problems because of the limitations of conventional 2-D representations. Many students find it difficult to understand how landforms from a topographic survey will impact a construction project, where a watershed is located, how beams and columns are connected in a building frame, what work will need to be done to excavate a foundation, or how to lay out a roadway. With the advent of new computer technologies, it is possible to take numerical 3-D data and render virtual computer models that are presented in 3-D, enhancing the learning experience in relation to both analysis and design in the civil engineering curriculum [1].

To this end, the College of Engineering at Valparaiso University has established the Scientific Visualization Laboratory to improve the learning experience for students for 3-D concepts that are hard to represent in conventional 2-D space [2-4]. Examples include electromagnetic fields, complex organic molecules, microelectronic circuit fabrications, force vectors, moving machines and their individual parts, terrain models, buildings, and bridges. Furthermore, the time dimension can be incorporated to create a 4-D model that can show the change over time of a 3-D model due to motion, loading, modifications, deterioration, and environmental effects. This paper describes our extension to the existing work done by the Scientific Visualization Laboratory to improve teaching methods in civil engineering by utilizing the 3-D displays of virtual reality hardware.

Computer and Software Systems

As computers increase in speed and processing capacity, prices continue to decrease, allowing greater access for consumer and educational use. Of note is the affordability of common PC computer systems that can power a 3-D model projection system, described in depth by Will and Johnson [2]. The advent of this technology brings the cost of virtual reality equipment, heretofore costing millions of dollars, down to the much more accessible price of $10,000 - $100,000. The equipment in this research uses this “low cost” virtual reality hardware.

In the present study, the VisBox™ virtual reality projection system was used in conjunction with a common PC running the Windows XP operating system. Three software applications were used: a common spreadsheet utility, AutoCAD Land Desktop [5], and Fledermaus [6], a graphing and visualization package for civil engineering data that has the capability of displaying on a 3-D projection screen. The spreadsheet utility can be used to process numerical data for use with AutoCAD Land Desktop, which in turn can be used to create models, such as land contours and roadway alignments. Fledermaus can use the AutoCAD model to create stereo images, which when viewed by polarized glasses will appear to be a virtual 3-D rendering.

Processing for 3-D Visualization

Fledermaus is a 3-D processing and display software package produced by Interactive Visualization Systems. It also allows for import of 3-D data from a wide variety of sources such as CAD programs, virtual reality formats, and XYZ ordered coordinates. It was decided early on to concentrate on two common data formats: DXF files produced by AutoCAD Land Desktop and XYZ ordered coordinates output as text from a common spreadsheet utility.

DXF files are standard text format files that can have large amounts of data about geometric entities such as length, color, thickness, and layer location. Layers are created in Fledermaus by importing one CAD layer at a time. For example, this would allow for contours and proposed road alignments separately or together when viewing a proposed land development. Color maps can be added to Fledermaus layers for ease of differentiation between contours of different height levels. Polylines or 3-D lines can be imported directly into Fledermaus for viewing.

XYZ ordered coordinates must be converted into a surface Fledermaus will recognize by using a companion program called DMagic. The DMagic program translates points to a solid surface with a color map for creation of an elevation legend. The surface can then be viewed with Fledermaus.

Once the entities are imported into Fledermaus, they can be shown as a 3-D scene either on a computer monitor or projected on the VisBox screen. Fledermaus is able to produce a split stereo mode for VisBox where one image is polarized vertically and another image is polarized horizontally which produces the simulated 3-D effect when viewed with polarized 3-D glasses. Figures 1, 2, and 3 show 3D images created using Fledermaus rendered as 2-D images.

Applications in the Civil Engineering Curriculum

The first use of the system was in the Fall 2004 semester to demonstrate what a long-standing homework and project assignment in land development (i.e. contours and road alignments) in a junior/senior-level CAD course should look like (Figure 4). The system is being used in Spring 2005 for instructional purposes for freshmen CE students taking surveying and CAD. In particular, these students are involved in creation of a topographic map in the surveying course, which in turn is rendered in CAD. The resulting CAD files are then ported to Fledermaus for viewing on VisBox to determine the accuracy of the students' calculations for the topographic map.

It is anticipated that the freshman taking part in the surveying course will be exposed to the 3-D visualization system in subsequent years as exercises for transportation, hydrology, structural design, and senior design projects are devised. In addition, this same freshman course will be using the 3-D visualization system for the required statics course that they will take in the Spring 2005 semester. It is anticipated that the required mechanics of materials course will be supported with the visualization system in the future.

It is anticipated that the current surveying (freshman-level, 2nd semester) and transportation (sophomore-level, 3rd semester) courses will be revised over summer 2005 to be a more tightly integrated class sequence topically, especially where 3-D concepts are presented. For example, the surveying course introduces students to concepts such as coordinate calculation and topographic mapping. The transportation course builds on this foundational information by introduction of concepts associated with route layout such as with determination of vertical and horizontal curves for highways. The same topics and assignments have been covered before the introduction of the 3-D system, allowing for comparison of the efficacy new 3-D system.

Conclusions

The necessity for students to understand the 3-D nature of civil engineering structures is paramount but not completely addressed with use of ordinary 2-D media. Low-cost visualization systems show promise for improvement of student learning and will be the subject of future study. The low cost of these systems point to their increasing use in classroom and laboratory settings. Integration of this technology into education must be predicated upon proper methods and associated software. In this work, we introduce the concept that visualization software in conjunction with virtual reality hardware may form an important extension to two areas of civil engineering education, and shows great promise for the future.

References

[1] P.C. Wankat and F.S. Oreowicz, *Teaching Engineering*. New York: McGraw-Hill, 1993.

[2] J.D. Will and E.W. Johnson, "Scientific Visualization for Undergraduate Education," in Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT, 2004.

[3] VisBox, Inc. http://www.visbox.com

[4] Valparaiso University Scientific Visualization Laboratory. http://diamond.gem.valpo.edu/~svl

[5] AutoCAD Land Desktop 2005. Autodesk, Inc. San Rafael, CA.

[6] Fledermaus, Version 6.1. Interactive Visualization Systems. Fredericton, New Brunswick, Canada.

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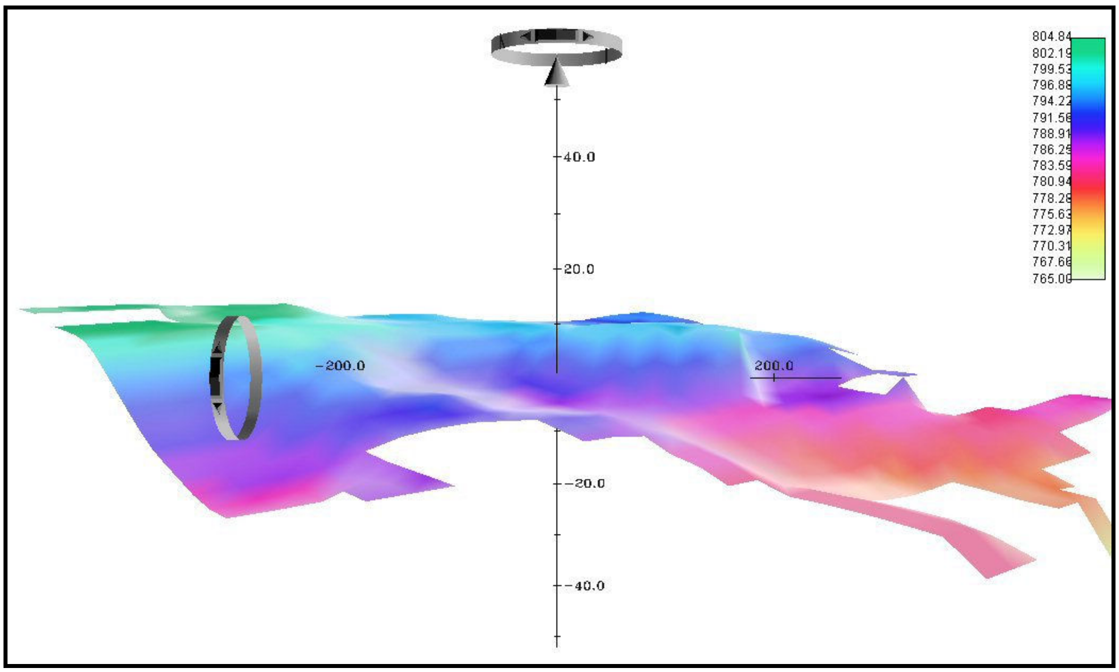

Figure 1 - Valparaiso University Library Site Topographic Map with Elevation Legend

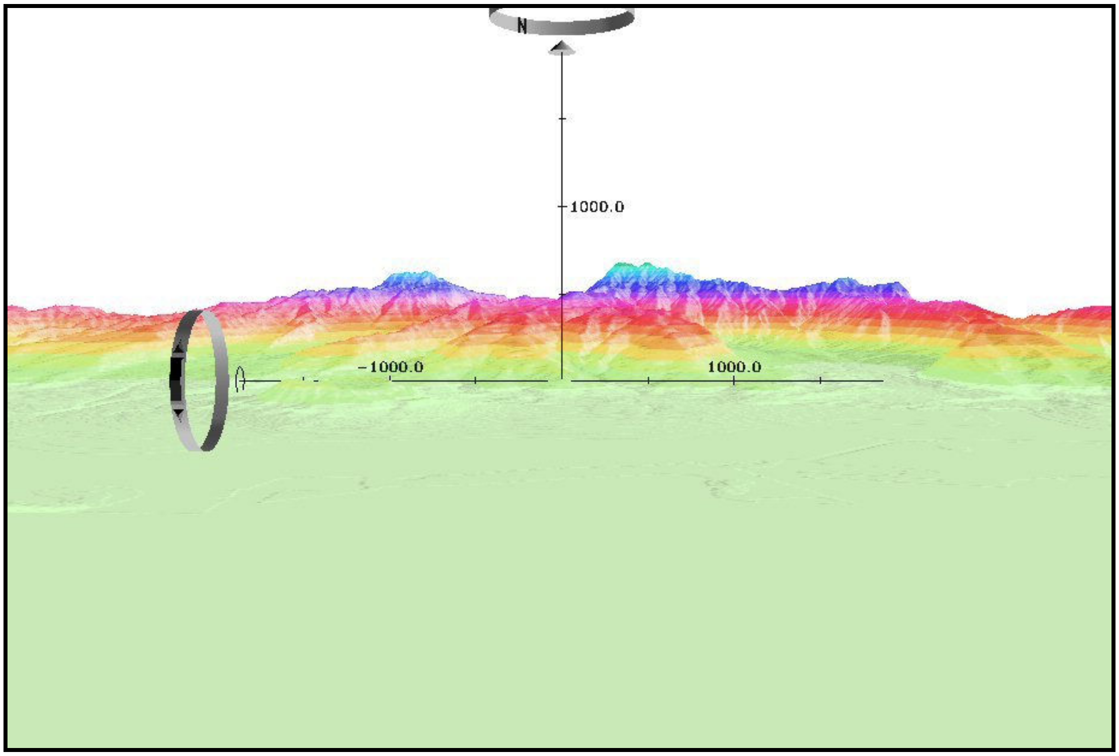

Figure 2 - View of Honolulu, Hawaii from Sea Level

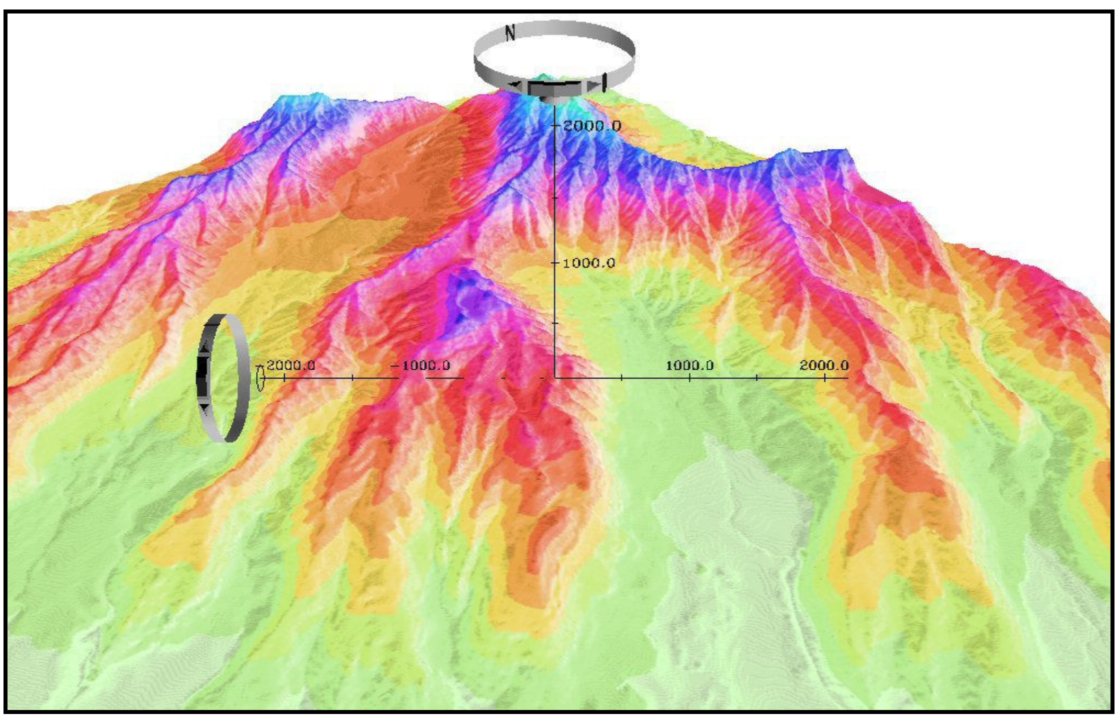

Figure 3 - View of Honolulu, Hawaii from Above

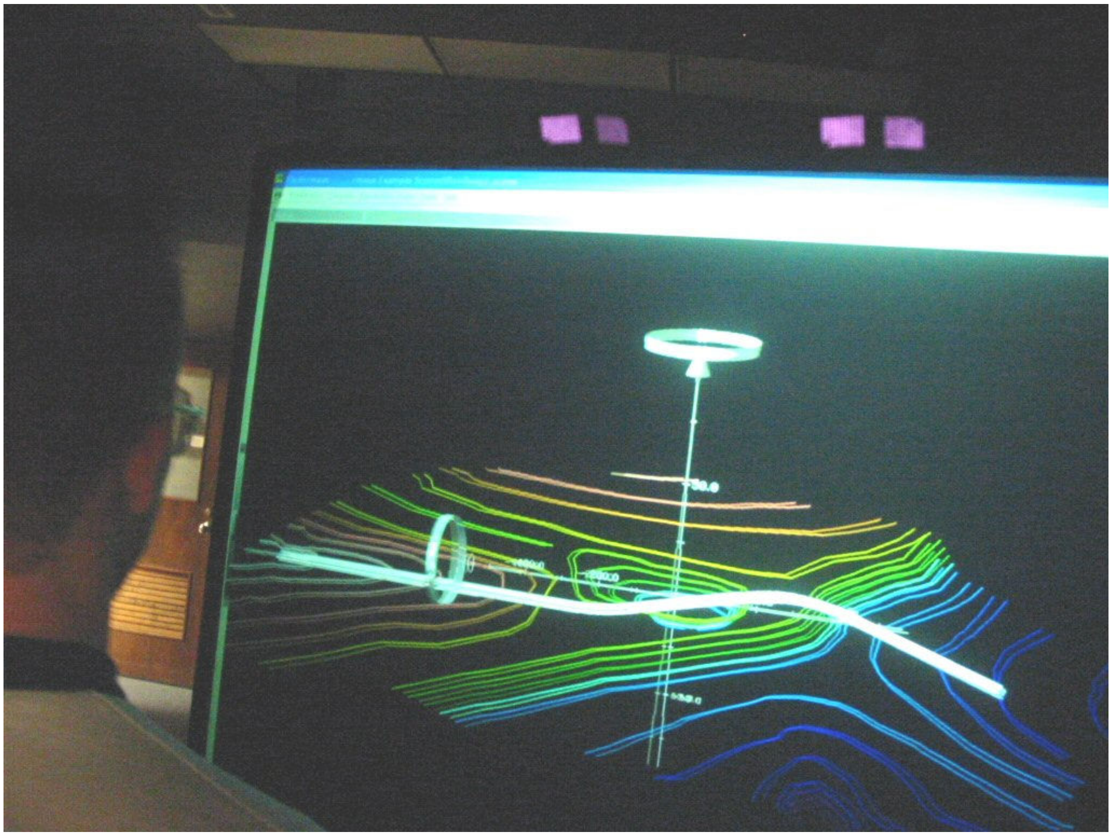

Figure 4 - Contours Map with Road Alignment Displayed on VisBox