An Interactive Virtual Environment for Learning Differential Leveling

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Abstract
In this paper, we describe the design and development of an interactive virtual environment whose objective is to help undergraduate students learn and review the concept and practices of differential leveling. The virtual environment includes realistic terrains and leveling instruments that look, operate, and produce results comparable to the physical ones. It will be integrated in surveying courses as a preparation, revision and assessment tool.

Keywords: Virtual learning environments; differential leveling; surveying education; formative evaluation;

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1. Introduction

The objective of the work reported in the paper was to develop a virtual environment for teaching differential leveling concepts and practices to undergraduate students. Differential leveling is one of the main topics covered in surveying courses; in general, during lecture the students learn fundamental principles of differential leveling, best practices to minimize errors and improve precision and accuracy, and finally evaluate and distribute the errors. In the lab students are introduced to leveling equipment and are given hands-on tasks to demonstrate proficiency at operating the instruments, accurately reading the measurements and correctly recording the data. Traditional methods for teaching differential leveling present several limitations. For instance, students work in teams and therefore it is difficult for the instructor to accurately assess the performance of each individual student; the ability to practice in the field is greatly affected by weather and lighting conditions; the number of terrains on which to practice is usually limited to the terrains that are available on the university campus; the students’ ability to repeat assignments and further practice with the equipment is limited by the availability of the instruments.

The tool described in the paper overcomes many of these limitations. It provides students with an opportunity to practice the concepts and procedures of leveling independently from team members; it allows students to practice regardless of weather or lighting conditions; it gives them the possibility to perform assignments in a variety of virtual terrains thus breaking the monotony of redoing the same exercise in the limited available space; it enables the students to repeat the assignments as many times as they need. Our virtual learning environment (VLE) includes realistic terrains and instruments that look, operate and produce results comparable to the physical ones. Furthermore, it is true to traditional surveying practices, as it requires the students to perform the same essential steps that are involved in a leveling exercise in the field.

The paper is organized as follows: in section 2 we discuss the benefits of virtual learning environments (VLE) and report prior work on VLE for engineering and surveying education. In section 3 we explain principles and practices of differential leveling and describe our VLE. Conclusion and future work are included in section 4.

2. Virtual Environments and Learning

An Interactive Virtual Learning Environment (VLE) is defined as a designed information space in which the information is explicitly represented, educational interactions occur, and students are not only active, but actors, i.e., they co-construct the information space [1]. The pedagogical benefits of interactive virtual learning environments have been examined (and are currently being examined) by researchers in the areas of computer graphics, cognitive psychology, visual cognition, and educational psychology. In general, research findings show that virtual learning environments can be more effective than traditional teaching tools [2; 3; 4]. Research also shows that VR technology is particularly suitable to mathematics and science education. VR technology presents concepts in concrete terms and offers a valuable alternative to the conventional study of mathematics and science, which is based primarily on textual descriptions and 2D representations [5].

Though progress has been less evident in engineering education [6]; some researchers argue that Virtual Reality is mature enough to be used for enhancing communication of ideas and concepts, stimulate the interest of engineering students and improve learning [7]. Some noticeable examples of engineering virtual laboratories exist.

In the area of surveying, Kuo et al. [8] have recently developed a virtual survey instrument (SimuSurvey) for visualizing and simulating surveying scenarios in a computer-generated VE, and studied the feasibility of introducing SimuSurvey in regular surveyor training courses. Results of the study indicated improved student learning outcomes and positive attitude toward including SimuSurvey in regular surveyor training courses. At Leeds Metropolitan University, UK, Ellis et al. [9]
have developed an undergraduate VR surveying application. The interactive software includes 360-degree panoramic images of sites and makes use of QuickTime VR technology. The application was evaluated with 192 undergraduate students; findings suggest that the interactive tool complements traditional learning approaches, maintains student interest, and reinforces understanding. At University of New Castle, UK, Mills and Barber [10] have implemented a virtual surveying field course which includes both a virtual fieldtrip and a virtual interactive traverse learning tool (VITLT). The goal of the tool is to improve understanding of surveying methods for first year students in the Geomatics degree. The application was evaluated by several Geomatics students; all subjects highlighted the potential of VITLT to help the learning and understanding of a traverse. At Purdue University, Dib and Adamo-Villani [11; 12] have developed a virtual learning environment for teaching and learning the surveying concept of chaining. A pilot study with a group of undergraduate students showed that subjects found the application effective for learning surveying concepts and practices and for getting feedback on their understanding of the subject.

Although some authors have documented that VR experiences provide advantages over more traditional instructional methods [13], studies of VR projects are still relatively rare and a need exists for investigations of VR in the undergraduate classroom.

3. The Virtual Learning Environment

3.1 Differential leveling

Differential leveling is the practice of measuring the height differences between a series of points of interests and/or the elevation of a point in relation to mean sea level. To perform a differential leveling exercise, students set up a level on a tripod and level it so that the line of sight is horizontal. A graduated rod is held vertically over the first point of interest and a reading made of the intersection of the cross-hair with the image of the rod (backsight - b). The same (or an identical) rod is then held vertically over the second point and a further reading made (foresight - f). The difference between the two readings is the difference in height between the two points:

\[ \Delta h = b - f \]

If \( b \) is greater than \( f \) then \( \Delta h \) is positive (i.e. there is a rise in elevation in moving from the first to the second point).

“This process can be repeated - the level can be moved to beyond the second point and the height difference between the second and a third point measured by the same process. Further repetitions will allow the height difference between widely separated points to be determined by accumulating the height differences between intermediate points. The distance from level to rod is dictated by the steepness of the terrain and the clarity of the image viewed by the observer. Usually the maximum sight length is restricted to 50-60m.” [14].

3.2 VLE educational content and interaction design

In the VLE, the students have the option to select from a database of terrains that vary in topography, vegetation, and obstacles. Once the terrain is selected the students have to exercise their good judgment on where to locate the tripod and the level in order to maximize access to the points of interest. The selected location of the level has great impact on the ability to complete the leveling exercise with accuracy and speed. A good placement of the level leads to more points measured from one single set up location, therefore less time to complete the exercise and less room for errors. Figure 1-top left shows the selected terrain and the placement of the level.
After placing the level, students need to calibrate the instrument correctly so that the level is plumb. If the instrument is not plumb, the level will not be measuring the horizontal line and this will lead to the failure of the exercise. Figure 1 (top right) shows a close-up of the level model. Students use the mouse to rotate the leveling screws in order to level the instrument (bubbles in the center). Once the instrument is set up properly, the software highlights the area within reach of the level. This area extends to cover all the points within 200 feet radius from the set up location where the instrument’s accuracy is optimal. The student should select points within this lighted area in order to avoid a situation in which the measuring rod is out of the range of the level. This could cause erroneous readings, hence leading to increased chance for errors. The next step for the students is to place the measuring rods on the various points of interest and record the readings on the rods (figure 1- bottom left) in the table (figure 1- bottom right). An accurate reading of the measurement will require the student to signal to the rod person directions to rock the rod, a common practice in the surveying field whose intent is to record the lowest measurement. The communication between the instrument person and the rod person is done via hand signal (in the case of the VLE no other student is involved in the process, thus the same student plays both roles). The character representing the student in the virtual environment gestures the corresponding hand signal based on the desired command. This practice is true to real practices in the field, where the students communicate via hand signals with the team members. Finally, the recorded measurements need to be documented in a tabular format. The students are required to record the measurements in the appropriate cells in the provided table (figure 1- bottom right); failure to record the measurement appropriately will result in failure of the exercise. The VLE captures the of the best industry practices and offers the students an opportunity to iterate and practice these best behaviors to improve accuracy and precision when doing the work in real world settings. A video demonstration of the VLE is available at http://www2.tech.purdue.edu/cgt/i3/leveling.htm

3.3 Technical implementation

The platform for the project is based on Unity 3D and Autodesk Maya software. We used Maya software to model, texture and animate the virtual instruments and characters. Interactivity with the 3D components was programmed in Java script using the Unity game development platform. The VLE is designed to run on hardware and software infrastructure that is already widely deployed in universities and students can use the VLE on low-end personal computers (PC/MAC) with low-end graphics cards.
4. Conclusion and Future Work

In this paper we have described the development of a virtual learning environment whose goal is to augment the teaching of differential leveling principles and practices to undergraduate students enrolled in surveying courses. The long-term goal of our research is to provide a demonstration that certain topics in surveying can be taught as or more effectively using virtual learning environments than by traditional methods. Future work will include formative evaluation of the VLE, subsequent refinement, and summative assessment of learning outcomes. Summative evaluation will be conducted once the VLE is fully completed to: (1) assess the overall worth and effectiveness of the VLE; (2) draw out key lessons learned from the project; and (3) determine the sustainability, transferability, scalability, and relative importance of the initiative in enhancing students’ understanding of surveying concepts and practices.

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References

