

Virtual Reality for learning construction surveying

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Abstract

This paper proposes the use of Virtual Reality (VR) as the enabling tool for delivering and learning construction layout and surveying. VR is used to provide an interactive learning experience through real-time computer generated imagery (CGI). The students learn and apply the theoretical part of the class through the interaction with the virtual surveying equipment in a virtual environment (VE). Our hypothesis is that the students' exposure to the virtual surveying equipment and the ability to practice at their own pace without worrying about making expensive mistakes will enhance the learning experience compared to current practices. In current practices, the students have limited access to equipment, they are constrained by the schedule and the learning pace of other team members, and are limited to the type of accessible terrain where they practice the skills learned in the class.

In the paper the authors highlight the benefits of the proposed method, describe the development of the virtual learning environment.

Keywords: education, construction, construction layout, surveying, virtual environment

1 Introduction & problem definition

The motivation for this paper comes from the challenges of teaching the basics of Surveying and Construction layout in the construction management curriculum. Surveying is the science of studying the 3D shapes of the earth curvature. Surveying concepts are founded in the geometry and vectors principals. In the settings of the construction layout, angles, distances and elevations are used to set up the building footprint at the correct location, establish level elevations and plumb vertical surfaces. The students seem to understand and grasp the theoretical aspects. However, when it comes to the application in the settings of a real life scenario, the students are constantly challenged in following all the steps to achieve the accuracy and precision that are sought by the surveying practices. Accuracy and precision are detriment to the success of any surveying task.

From the students' perspective, the students would benefit more if they are provided with:

- One to one mentoring and guidance in the learning process
- Additional time to practice with the equipment
- Less dependency on team members
- Instant response on accuracy of measurement
- Access to standardized equipment

It has been the observation of the professors that the individual student effort can not be documented accurately. Students have to work with team members to complete the simplest tasks.

Measuring with steel tapes require having two students, each student at end of the tape exercising the proper techniques in order to achieve accuracy in measurements. It only takes one student to make a mistake in order for the team to get the wrong measurement. It is not uncommon for good students to get penalized for the mistake of another teammate or the opposite case scenario. Currently there is one professor working with a group of students. To achieve the one to one training, one would need to have one trainer for every student. To accommodate the students, the trainers will need to be available at all the times the students are willing to practice. Team members will also need to be available for their teammates in order to achieve these goals. For obvious reasons, this is not practical or feasible to achieve. Currently students can be penalized for the mistakes or inaccuracy of one of their team members, a mistake not of their own. Students have limited access to the equipment especially with larger groups and limited surveying equipments in laboratories. Students' time to practice is limited to their teammates' availability for practice as well.

This study proposes the use of Virtual Reality (VR) to provide an interactive learning experience through real-time computer generated imagery (CGI) as the enabling tool for delivering and learning construction layout and surveying. The students learn and apply the theoretical part of the class through the interaction with the virtual surveying equipment in a virtual environment (VE). This approach will offer the students the possibility to control the system and be fully responsible for the outcome and the results of their respective choices. The students' exposure to the virtual surveying equipment and the ability to practice at their own pace will allow the student to have immediate feedback, complete independence of their team members, monitored by the computer the student's efforts are documented and accurate feedback is given to the student. The computer offer various types of terrains for the student to practice the skills learned in the class in different topographical settings.

2 Methodology

In order for the program to control the documentation of the student work and interaction with the VR model during the practice and training, it is critical to have the procedures outlined as step by step measurable list of actions. The goals and objective have to be clearly stated and organized; offering the student a logical sequence of exercises presenting challenges with incremental ratio of difficulty. Starting with simple cases where the students master the basic techniques then moving on to more challenging tasks that add to the complexity of the topic and simulate multiple real case scenarios. For the various tasks that are going to be studied in the class, the student will have to master sets of theoretical knowledge and complement the theory with practical expertise. The following tables highlight the core competencies and activities required for the competency areas of measuring horizontal distances, differential elevations and vertical and horizontal angles using the basic instruments such as steel tape, level and the transit.

Table 1 illustrates the list of the core competencies in surveying and construction layout. The core competencies consist of the students' ability to measure horizontal distances, determine differential elevations, and measure vertical and horizontal angles. Measuring horizontal distances can be achieved with various methods. In simpler cases, such as on a flat horizontal surface, the steel tape can be the only tool needed to achieve such task. While in more complex scenarios, the level or the transit can be used to achieve the same objective.

Table 2 summarizes the theoretical and the practical challenges that are associated with the specific tools. For example, when measuring with the steel tape, the users have to adjust for temperature errors, tension, and sometimes use geometry or trigonometry principles in order to measure a horizontal distance. For instance, a user can measure the slope distance, and knowing the differential elevations can calculate the horizontal distance. In addition to the theoretical skills presented above, the user has to adjust for practical measures in the field in order to achieve the

accuracy and precision. Field competencies consist of correct alignment, using the appropriate tools and procedures.

While the core competencies and activities are used as guidelines to design assignments and exercises, the student work is documented and evaluated based on the step by step procedures illustrated by the flowchart in figure 1 thereafter.

Table 1. Core competencies and corresponding possible tools

Tools	Steel Tape	Level	Transit/Theodolite
Horizontal Distance	X	X	X
Differential Elevation		X	X
Vertical & Horizontal Angles			X

Table 2. Theoretical and practical challenges

Steel Tape	
Theoretical Challenges	Practical Challenges
Correction error due to temperature changes Correction due to tension and sag in tape The concept of measuring Horizontal distance Vs. Slope distance	Error due to alignment Break down the distance method Using the Plumb bob properly Use of chaining pins
Level	
Theoretical Challenges	Practical Challenges
Concept of differential Leveling Calculation of error Filling the tabular information Maximum allowable error Distribution of error	Proper Instrument set up Choice of tripod location Holding the measuring rod properly Reading the measuring rod properly Safe field practices/practice common sense
Transit/Theodolite	
Theoretical Challenges	Practical Challenges
Mathematics and trigonometry background Concepts of vectors Calculation of coordinates based on angles and distances Traverse calculation Distribution of error	Proper instrument set up Techniques for proper set up on a benchmark Proper techniques to read the horizontal and vertical angles Finding True North Safe field practices/practice common sense

The following guidelines shown below, illustrate the rational and procedure designed for measurement of Horizontal distances using steel tape:

Once the program is started, the following directions are posted:

- Place head of Tape at point A
- Place end of tape at point B
- With help of Plumb Bob, insure that head of tape is precisely located on top of point A
- Similarly, ensure that end of tape is precisely on top of point B
- Using Hand level, make sure the tape is level,
- With the use of the tension meter, make sure the appropriate tension is exerted on the tape

The student work is assessed based on the alignment of both ends of the tape with the points on the ground, the levelness of the steel tape, the tension of the tape, the accurate reading of the tape, and the accuracy and precision of the work. Below is an illustration of the decision making and the documentation of the computer program in order to assess the student's work.

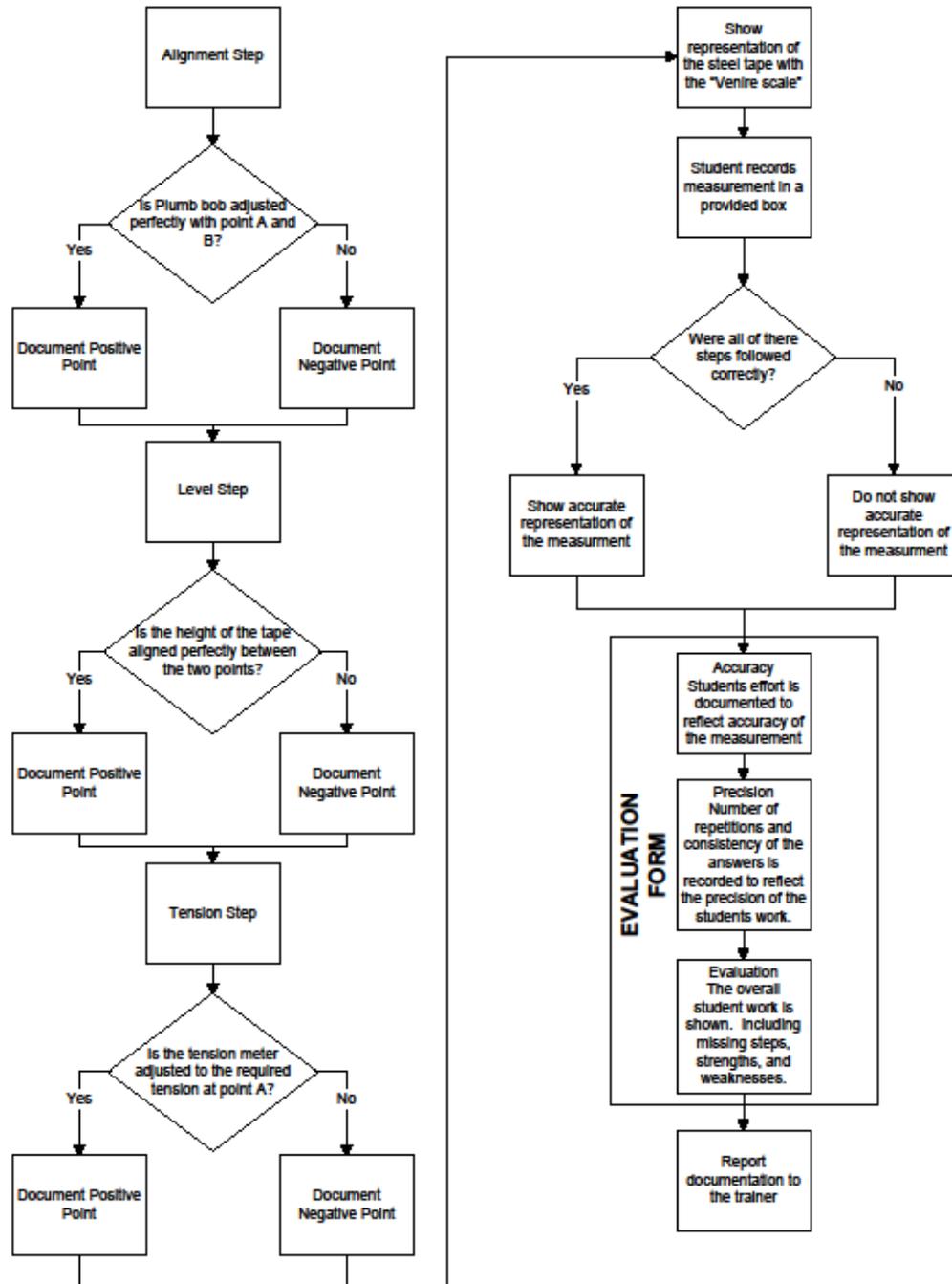


Figure 1, Rational for Documentation and Assessment of student's efforts

Figures 2, 3 & 4 are screen shots from the program showing the progression of the student starting with figure 2 the initial screen illustrating the guidelines and objectives the student needs to follow in this module. Figure 3 show the first screen shot prior to the student making any adjustments as to levelness of tape, adjustment for tension, plumbness on top of the starting and ending points. Figure 4 shows the end goal where the student has adjusted for all the criteria.



Figure 2, Initial screen shot showing directions

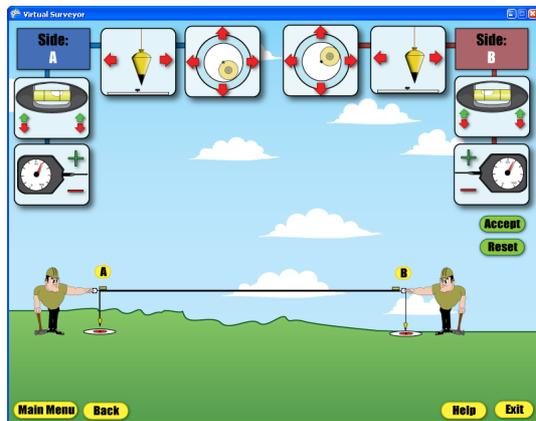


Figure 3, Initial settings prior to any adjustments

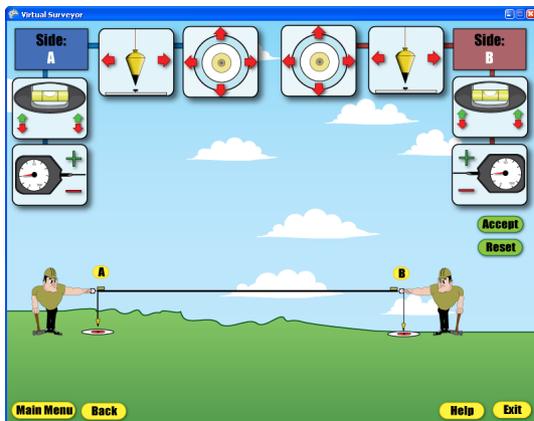


Figure 4, Target settings showing all adjustments

3 Benefits of proposed method

- One to one mentoring and guidance in the learning process:

The computer model documents the student efforts, share the results with the student highlighting the missing steps, the accurate steps followed and the results found. The detailed feedback supports the mentoring process and help the student achieve the learning that is sought form this exercise.

- Additional time to practice with the equipment:

Considering that students are working independently at their own pace using the computer model, students are not limited to all the constraints such as access to equipment, and teammates available to assist in the completion of the tasks and weather.

- Less dependency on team members:

Working at own pace each student control the complete process assuming the various roles needed to complete the process and therefore does not need teammates to rely on.

- Instant response on accuracy of measurement and assessment of students work:

Computer model shares report at end of the exercise showing the student documentation of efforts and analysis of strengths and weaknesses. Students can repeat the process to enhance their knowledge, skills and performance.

- Access to standardized equipment:

The steel tape available at most facilities are abused by students as a result of wear and tear, and are seldom standardized. As a result, it is very common that students who follow all steps and procedures accurately might not be able to achieve the exact accuracy resulting in discouragement to the students' efforts. With the proposed model the students gain confidence by achieving the levels of accuracy.

4 Conclusion

The proposed model provides students with a variety of unfamiliar environments that are not usually available locally. Students are limited to working areas around campus in designated areas and do not have the exposure to work in various terrains such as steep slopes and rough topography without having to traveling to such locations. The VR environment offer a virtual surveying learning tool, where the students can have the experience of working and experimenting with various techniques and a wide variety of environments without the need to travel. The students' learning is enhanced based on the additional available training and the detailed reporting of their efforts. This contrasts with current practices using real-world equipment, access to equipment is limited to class hours only, schedule and learning pace of other team members, limited accessibility to the surveyed area and

environmental conditions. In addition, the current surveying class is taught in groups. Students are teamed up in order to help each other complete the labs. This makes it hard to evaluate the performance of one individual when the overall performance is affected by the group performance. The proposed model offers a more accurate evaluation tool to assess the individual student's knowledge and practical skills. Students are evaluated based on their personal effort and interaction with the virtual surveying equipment. In this approach, a student will have to assume the various roles and master all the roles without relying on colleagues to assist during the process.

Currently, the VR model for teaching surveying and construction layout is in the planning phase and early development. One module relative to the measurement of horizontal distances is being developed and will be tested over the next 3 months. We are seeking funds to develop the full version of the envisioned complete model to include all the modules relative to the advanced steel tape measurement exercises, the level practices, the transit and theodolite and GPS-Global Positioning devices. It is anticipated that the results of the first module will be shared during the presentation.

References

- BELHADJ, F., 2007. Terrain modeling: A constrained fractal model, ACM International Conference on Computer Graphics, Virtual Reality and Visualisation in Africa, 2007, pp. 197-204
- BERNOLD, L.E., 2002. Spatial integration in construction, Journal of Construction Engineering and Management, 2002, 128, (5), pp. 400-408
- BOUSSABAIN, A.H., GREW, B., COWLAND, S., AND SLATER, P., 1999. A virtual reality model for site layout, Novel Design and Information Technology Applications for Civil and Structural Engineering, 1999, pp. 77-82
- CASTILLO-EFFEN, M., ALVIS, W., CASTILLO, C., MORENO, W.A., AND VALAVANIS, K.P., 2005. Modeling and visualization of multiple autonomous heterogeneous vehicles, Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics, 2005, 3, pp. 2001-2007
- JUN, G., AND QING, Z., 2006. Research on the key technologies of 3D spatial data organization and management for virtual building environments, Proceedings of SPIE - The International Society for Optical Engineering, 2006, 6421, pp.
- LEE, W.L., AND GREEN, M., 2006. Automatic layout for 3D user interfaces construction, Proceedings - VRCIA 2006 ACM International Conference on Virtual Reality Continuum and its Applications, 2006, 2006, pp. 113-120
- LESKO, C., AND PICKARD, J., 2009. Design considerations for virtual classroom and laboratory environments, ASEE Annual Conference and Exposition, Conference Proceedings, 2009, pp. BOEING
- LI, C.-M., YE, H., CHEN, S.-F., CHIANG, T.-Y., AND LIEN, L.-C., 2008. Virtual reality learning system for digital terrain model surveying practice, Journal of Professional Issues in Engineering Education and Practice, 2008, 134, (4), pp. 335-345
- MITCHELL, C., TIAN, G.Y., GLEDHILL, D., AND TAYLOR, D., 2004. Web-based interactive 3D visualization for business and building management, Proceedings of the Eighth IASTED International Conference on Internet and Multimedia Systems and Applications, 2004, pp. 409-413
- NIKOLIC, D., JARUHAR, S., AND MESSNER, J.I., 2009. An educational simulation in construction: The virtual construction simulator, Proceedings of the 2009 ASCE International Workshop on Computing in Civil Engineering, 2009, 346, pp. 633-642
- SUN, Q., STUBBLEFIELD, K., AND GRAMOLL, K., 2000. Internet-based simulation and virtual city for engineering education, ASEE Annual Conference Proceedings, 2000, pp. 3725-3737
- XIAO, A., BRYDEN, K., AND BRIGHAM, D., 2004. Virtual reality tools for enhancing interactive learning, ASEE Annual Conference Proceedings, 2004, pp. 15305-15317
- ZHU, J., LIN, H., XU, B., AND HU, Y., 2008. Real-time visualization of virtual geographic environment using the view-dependent simplification method, Proceedings of SPIE - The International Society for Optical Engineering, 2008, 7143