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SimuSurvey X: an improved virtual surveying instrument running off a game engine

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Abstract

This paper presents the continuing progress of the SimuSurvey X project. SimuSurvey is a virtual surveying instrument purpose-built for survey training. SimuSurvey X supersedes SimuSurvey, the original version that was developed by the authors for visualizing and simulating surveying scenarios in a computer-generated virtual environment. The concept of SimuSurvey has already been demonstrated to be successful in a user test of 323 students. User feedback in our previous research indicated that user interface design and deployment were two of the major drawbacks in the original SimuSurvey. Addressing these concerns, we transferred the SimuSurvey X system to the XNA game engine. It supports high-quality real-time rendering and a versatile user controller. Additionally, since XNA can be run on an Xbox gaming console, the deployment of SimuSurvey X is easier and more versatile. With these improvements to the interface and deployment, we believe that SimuSurvey X is a significant step closer to meeting the needs of educators and learners in the area of survey training. We have recently implemented version X at three vocational schools to obtain feedback from teachers and students. A comparison of the original version and this new version will be made to measure the effectiveness of the enhancements.

Keywords: game engine, engineering education, surveyor education, virtual equipment, XNA, XBox

1 Introduction

Surveying technologies have become indispensable in modern life. They play important roles in the engineering of buildings, highways, railroads, bridges, tunnels, dams, and even urban development (Wolf and Ghilani, 2002). Currently, many vocational schools and universities in the field of civil engineering and architecture offer surveying courses to train novice surveyors. A typical surveying course includes both indoor instruction, which covers surveying-related theories, and outdoor fieldwork, which provides students with opportunities to familiarize themselves with the proper use of surveying instruments (Noéh, 1999). The major drawback of this method of education stems from the constraints imposed due to the availability of physical instruments. Since most schools cannot afford to provide one instrument for each student, students need to share the instrument and take turns practicing. This can reduce students' learning performance and motivation. Rain or foggy weather may also impede outdoor learning activities.

To overcome these drawbacks, several computer-based teaching aids have been developed specifically for improving the instruction of surveying courses. In order to solve the above problems, many instructors have introduced electronic teaching aids into their classes. For example, Bai (2007) used video to demonstrate survey procedures. Yeh (2005 and 2006) employed virtual reality technologies to simulate the environment for surveying. Li *et al.* (2007) created a virtual reality learning system for surveying practice on digital terrain models using a virtual total station. These teaching aids can assist instructors in explaining the concepts regarding the spatial relationship between the survey instrument and the targets.

Based on the successful experiences of the aforementioned instructors, Lu *et al.* (2007) developed SimuSurvey, a computer-based survey training tool which makes it possible to accurately simulate instrument manipulation. The user interface of SimuSurvey is as shown in Figure 1. Kuo *et al.* (2007) conducted a feasibility study on the application of SimuSurvey in survey training and evaluated the effectiveness of SimuSurvey.

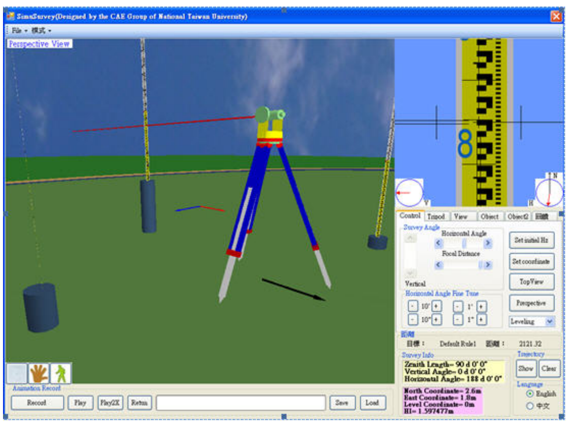


Figure 1. The user interface of SimuSurvey

The concept of SimuSurvey has already been demonstrated to be successful in a user test of 323 students. User feedback in our previous research indicated that user interface design and deployment were still two of the major drawbacks of the original SimuSurvey.

The rapid development of computer graphics technology has enabled software developers to create more versatile visual applications. The latest graphics technologies often first appear on game consoles for entertainment purposes. Since game consoles offer good visual effects and user interfaces, they can also become suitable platforms for engineering simulations.

XNA is a set of game development tools with a managed runtime environment provided by Microsoft Corporation. The framework and application program interfaces (API) of XNA are helpful in shortening development times, and games developed using XNA can easily work on computers and Xbox game consoles. The Xbox 360 is a game console produced by Microsoft with high-definition video and a high graphics processing speed. In general, it provides better 3D visual effects and an easier user interface than a general purpose personal computer. The benefits that an XNA gaming platform can provide for virtual surveying instruments are: (1) as modern game consoles often have fantastic visual effects and provide 360 degrees of navigation, those capabilities provide the users with a better awareness of the spatial environment; (2) an improved user interface for operating virtual surveying instruments; and (3) game consoles have a unified hardware standard for easier deployment, teaching and promotion. Frequently, graphics-oriented applications have quite different appearances on PCs with different hardware, since the rendering powers differ from one to another. However, the game console delivers a consistent experience. As well, the XNA online marketplace can be the sales channel of SimuSurvey X in the future. Existing gamers' forums and online communities can also help to quickly start development projects.

2 Research objective and research scope

2.1 Research objective

The purpose of this research is the continued improvement of the usability and teaching effectiveness of SimuSurvey over previous efforts. By using the XNA gaming platform, we developed a new virtual surveying instrument named SimuSurvey X with improved visual effects and user interface.

2.2 Research scope

SimuSurvey X provides a virtual environment for survey training with various surveying instruments and accessories. The virtual instruments include leveling, theodolite and total station; the virtual accessories include level rulers and poles. SimuSurvey X provides five scenarios for surveying missions: leveling surveying, horizontal angle surveying, vertical angle surveying, traverse closed surveying and free mode surveying.

During the development, we focused not only on technical issues, but also considered creativity and aesthetics. We made use of user-centered design (UCD) methods in the implementation phase to help find problems regarding the user interface as early as possible. The resulting virtual training tools had to fully utilize the features and advantages of the gaming platform.

After the software implementation, we also prepared SimuSurvey X teaching material to accompanying the real instrument practices in surveying courses in vocational schools and universities. During the promotion activities, we conducted some user tests to collect user feedback, then analyzed the results to identify its usability and teaching effectiveness.

3 The process of implementation

3.1 Software development

In this research, we adopted an iterative and incremental development model and a user-centered design, resulting in a software redevelopment (or improvement) approach we called I&I-UCD. Figure 2 illustrates the features of the I&I-UCD approach. The redevelopment process is a sequence of iterations, each of which is composed of five incremental stages. Two sub-iterations exist in both the design and implementation phases in which user tests are performed to evaluate the effects of design on implementation until all identified usability problems are addressed. The following sections show the actual contents of each phase.

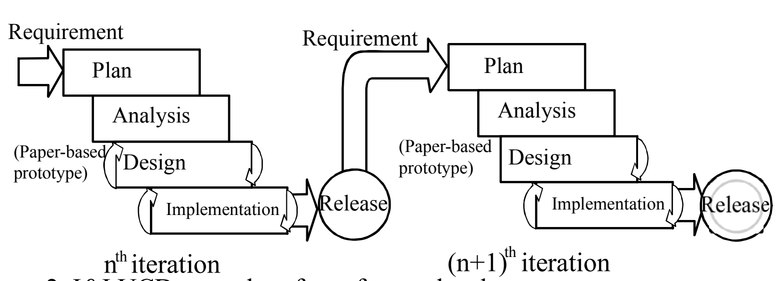


Figure 2. I&I UCD procedure for software development

3.1.1 Plan phase

Games are intrinsically non-sequential. We figured out all the concepts with two different types of documents. One is the game structure (3.2) for the presence of the branching tree structure. Another one is the storyboard (Table 1) for the description of the appearance on-screen and the interactions between the game and the users.

3.1.2 Analysis phase

The major goal of the analysis phase is to define concrete and detailed specifications that need to be achieved by the end of the redevelopment. There are two major tasks in this phase. The first task is to analyze the structure of each joint of the surveying instruments; part of the result of this is shown in Figure 3. The second task is to gather and analyze the current material for the survey training in SimuSurvey X.

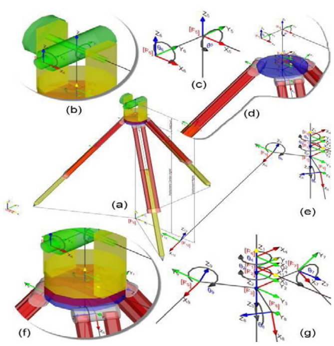


Figure 3. The analysis of the kinematics model of the surveying instruments

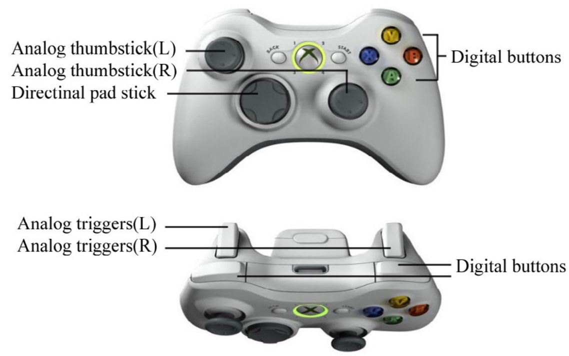


Figure 4. Xbox 360 controller

3.1.3 Design phase

The Xbox 360 controller is designed for exclusive use with the Xbox 360 game system. The correlation between the operations of the controller's buttons, or thumbsticks, and the controls of the components on the actual instrument need to be taken into consideration. In some cases, users need to manipulate multiple functions simultaneously without interfering with additional mode switching. To keep up with experienced players, we also referenced the general designs of other simulation games on the market. The Xbox 360 controller is as shown in Figure 4; it includes two expansion slots, two analog triggers, and two analog thumbsticks, for a total of eight digital buttons (four of which make up the joypad).

3.1.4 Implementation phase

The major activities in the implementation phase include: (1) creating the 3D models of surveying instruments, accessories and scenes; (2) building the correlation between the virtual instrument and the actual instrument, and developing all the functionalities of the virtual instrument; and (3) the testing and modification of software function and usability.

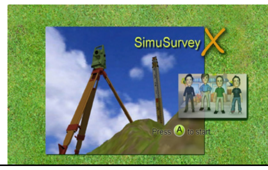
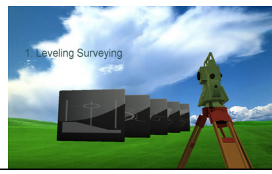
3.2 Game structure

The game structure defines the internal causal relationship over the course of the game. In this design, the user chooses the desired training item first. Every surveying task comes with a set of instruments and accessories within a paired virtual environment, and all the arrangements are intended for a specific training purpose. Once the user enters the virtual environment, he can iteratively switch between various modes and manipulate the instrument in different modes to accomplish the surveying task. These modes include a 3D navigation mode, a survey mode, a result/replay mode and a configuration mode.

3.3 Storyboard

'Storyboard' defines the screen design and the user interactions of the game, as shown in Table 1. It includes the description of the virtual environment, the user's possible operations, the visual feedback and the resulting scene.

Table 1. Part of the storyboard of SimuSurvey X

Item	Screen design	Interactions
01		A short animation of flying over the ground from a camera's perspective. The clouds keep moving until the user presses Button A. Jump to item 02.
02		The surveying task selection menu includes 5 virtual scenarios. Each contains the specific terrain, instruments and accessories. Jump to item 03 after the selection.
03	…	The following items are omitted.

4 Results

The SimuSurvey X program has been realized and deployed successfully on an Xbox game console, as shown in Figure 5(a). The accomplished functions of SimuSurvey X are discussed in the following sections.

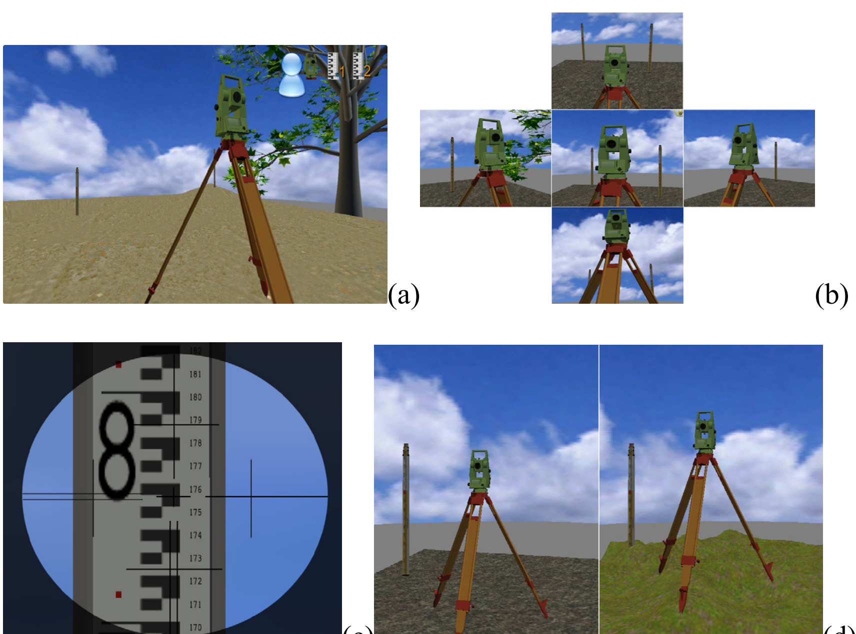


Figure 5. Screenshots of SimuSurvey X: (a) in the navigation mode, icons in the upper-right corner show the controlled object, (b) views of the object at different angles (c) observation through the telescope on the instrument, (d) the height of the object alters according to the terrain.

4.1 Looking around in the first person perspective

In the 3D navigation mode of SimuSurvey X, the user is immersed in the virtual environment and can move freely in any direction, as shown in Figure 5(b). Through these observations, the user will easily gain spatial awareness of the relationships between objects in the virtual world. In comparison to 2D diagrams, 3D navigation can lead to a more realistic experience for the user, and is also closer to real-world surveying.

4.2 Manipulation of the virtual instrument

When carrying out survey activities, users look through the simulated telescope and aim at the target ruler or rod by rotating the instrument horizontally or tilting it vertically until the crosshairs overlap on a desired position. The next step is to tune the focus until the image is clear enough for the user to get accurate readings, as shown in Figure 5(c). All the important controls of surveying are simulated, as mentioned above, including horizontal and vertical circular graduations, crosshairs, axis of sight, azimuth, reverse mode, and others.

4.3 Terrain model

Terrain is an important feature in survey training. Very often, surveying will take place in areas that include hills, valleys, or rivers. In SimuSurvey X, when the user moves the instrument, level ruler or pole in the virtual environment, the moved objects will alter their heights according to the elevation of the current location, as shown in Figure 5(d). This feature is also an improvement in SimuSurvey X over the previous version.

4.4 Record/ replay

SimuSurvey X records the whole surveying process and let the users watch their every single step in detail after the practice. Users can pause at any time on a single frame to find out the problems that they encountered. The surveying skill of the surveyor and the quality of the teaching course can be improved through repeated checking and revision.

5 Ongoing work

This research focuses not only on improvements to the visual effects and the user interface of the survey training tools, but also on integrating the features of the Xbox game console to increase the extent of the application. The following are some of the ongoing works of SimuSurvey X.

5.1 Cooperative surveying

In SimuSurvey X, we also designed larger and more advanced tasks for a team of students to work on together, with each of the participants playing a unique role in the surveying activity. In fact, surveying tasks in real life often need two or more people to work together to complete the task. Since they need to communicate with each other much more often during the practice of surveying, the wireless headsets of the Xbox that lets players chat and send voice messages can be used in the cooperative surveying mode of our application. Instructors can also join the surveying activity at the same time to observe the progress and give hints or help as needed.

5.2 Video playback

Video clips taken from actual instruments can be used as an aid or comparison with the virtual tools. It helps users to get a better impression for when they operate the actual instruments. Games created with XNA Game Studio can have video playback functionality. This feature enables our application to use video assets as a part of our teaching materials, which will also enrich the contents of SimuSurvey X.

6 Conclusions

SimuSurvey X has achieved its first goal and released the beta version in December 2009. We have also started preparing teaching materials to accompany SimuSurvey X in the promotion activities beginning in February 2010. We will also analyze and evaluate the survey training effectiveness of SimuSurvey X during those activities. Compared to the previous version, SimuSurvey X provides more vivid and realistic visual effects. The new user interface also increases the usability and makes it more accessible to users. The experience of the design of SimuSurvey X can be a reference for future development of other supplementary tools for engineering training courses. Through the improvement of survey training, more professional surveyors can be trained to a higher degree of skill, and thus advance the engineering industry.

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References

BITTNER, K. and SPENCE, I., 2006. *Managing Iterative Software Development Project*. Massachusetts: Addison Wesley Longman,.

HENDRIX, T.D. and SCHNENIDER, M.P., 2002. NASA's TReK project: a case study in using the spiral model of software development, *Communications of the ACM*, 45 (4), 152-159.

ISO 13407, 1999. Human-centered Design Processes for Interactive Systems. *International Standard Organization*.

KUO, H.L., Kang, S.C., LU, C.C., HEIEH, S.H. and LIN, Y.H., 2007. Using Virtual Instruments to Teach Surveying Courses: *Application and Assessment, Computer-Aided Engineering Report* 2008-3, Department of Civil Engineering, National Taiwan University, Taipei, Taiwan.

KUO, H.L., KANG, S.C., and LU, C.C., 2007. The Feasibility Study of Using a Virtual Survey instrument in Surveyor Training. In: *Proceedings of the 2007 International Conference on Engineering Education (ICEE 2007), September 3-7, 2007, Coimbra, Portugal*.

LARMAN, C., 2004. *Agile and Iterative Development: A Manager's Guide*. Massachusetts : Addison Wesley Longman,.

LI, C.M., YEH, I.C., CHENG, 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*, Vol. 134, No. 4, pp. 335-345. Doi: 10.1061/(ASCE) 1052-3928(2008) 134:4(335).

LU, C.C., KANG, S.C., and HSIEH, S.H. (2007). SimuSurvey: A Computer-based Simulator for Survey Training. In: *Proceedings of CIB 24th W78 Conference Maribor 2007 &14th EG-ICE Workshop & 5th ITC@EDU Workshop: Bringing ITC knowledge to work. Maribor, Slovenia, June 26-29, 2007, pp.743-748*.

LU, C.C., SHIH-CHANG KANG, SHANG-HSIEN HSIEH, RUEI-SHIUE SHIU, 2008. Improvement of a computer-based surveyor-training tool using a user-centered approach, *Advanced Engineering Informatics*, doi:10.1016/j.aei.2008.07.001.

NOEH, F., 1999. *Training for the Architecture Students in Surveying at the Technical University of Budapest, Periodica polytechnica Civil Engineering*, 43 (1), 55-61. http://www.pp.bme.hu/ci/1999_1/ci1999_1.html

PAASIVAARA, M. and LASSENIUS, C., 2003. *Collaboration practices in global inter-organizational software development projects, Software Process: Improvement and Practice*, 8 (4), 183-199.

ROSSON, M.B. and CARROLL, J.M., 2001. *Usability Engineering: Scenario-based Development of Human Computer Interaction, first ed.*, Morgan Kaufmann, San Francisco.

SEFFAH, A., GULLIKSEN, J. and DESMARAIS, M.C., 2005. *Human-centered Software Engineering: Integrating Usability in the Software Development Lifecycle*. Netherlands: Springer.

YEH, I. C., 2005. *Virtual Reality Learning System for Surveying Practice , National Science Council, Taiwan, Tech. Rep.* NSC93-2520-S-216-001, Jul (in Chinese).