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A Testbed to Measure the Effectiveness of 3D Travel Interfaces for Virtual Environments *

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A Testbed to Measure the Effectiveness of 3D Travel Interfaces for Virtual Environments

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Abstract – This paper describes the design and implementation of a testbed to measure the effectiveness of 3D travel interfaces for virtual environments. The goal of this application is to increase the efficiency of user testing by automating the data collection process. This can benefit HCI researchers involved in this field.

Keywords – Measurement, data acquisition, human-computer interface, human performance, virtual environments

I. INTRODUCTION

For a designer of virtual environment (VE) system, the selection of a good user interface is a key factor to determine its usability and thus maximize the possibility of success with the user community.

Although methods for measuring the usability of systems in general are already available and are even standardized [1], no particular tool or method is currently available to instrument human performance in VE. As a result, each time someone wants to evaluate the effectiveness of a specific user interface for a VE system, an ad-hoc human performance measurement system has to be designed and implemented.

Several tasks can be accomplished by using VE, but researchers identified four universal tasks that are common to most of the systems. These are: navigation, selection, manipulation and system control [2].

Our work here focus on the travel task, which is the motor component of the navigation task, the cognitive component being way finding, also known as spatial orientation. The travel task is a key aspect of VE systems and designers must carefully design their systems to make sure that their travel interfaces are usable and allow the participants to easily and effectively accomplish their tasks.

Although several studies have been conducted for immersive environments [3,4,5,6,7,8,9], to date, the selection of interaction techniques for VE applications has primarily been done on a casual basis without a careful evaluation of performance, engagement or presence [10,11]. The same as for other human-computer interfaces, several interaction techniques are possible for virtual travels, and their empirical evaluation is important to improve our understanding [3, 12,13,14,15].

In order to facilitate the empirical evaluation of travel techniques, we developed a set of requirements for a travel interface testbed and implemented them as part of a VE viewer.

This paper thus describes these requirements and the rationale behind, as well as the particular architecture used for the implementation of this software testbed.

II. REQUIREMENTS ANALYSIS

The empirical evaluation of travel techniques requires collecting information on the performance of participants while they carry out an experimental travel task. This information can then be recorded for later use for the measure and statistical analysis of participants' performance in relation with several performance criteria.

A. Time

The information collected during an experiment must be associated with a precise moment. In that sense, time measure is essential to accurately record and evaluate the timeline of a participant's actions and displacements. In addition to that, the moment of the recording should be indicated in the recorded data filename, in order to easily trace back the information for later post-processing phases.

B. Avatar Position

The position of the avatar in space in the virtual scene is another important datum for performance analysis. When combined with time data, this allows us to analyze not only the path followed in the virtual scene, but also the speed of motion at each point along that path, as well as the total distance traveled in the virtual scene.

C. Viewpoint Orientation

The viewpoint orientation is also needed to conduct a performance analysis. When combined with time data and avatar's position, this allows us to reconstruct the visual path followed by a participant in the virtual scene.

D. Cursor Position

Recording the mouse cursor position on the display, along with the rest of the information described in this section will allow better observing and understanding of participant's actions related to the mouse.

E. Other Inputs

In order to complete the performance analysis, it is important to record the other inputs of the participants along with all the details relevant to the analysis.

These inputs can be of different nature. Therefore, in certain cases, this information could allow to identify when in the experiment a participant pressed a mouse button, a key on the keyboard, or any other action, using another discrete input device.

To recognize multiple inputs, we used a bitwise encoding, where each bit of an integer is associated with the state of a particular discrete input. By screening the collected data, we can then know the exact moment where an event occurred, as well as the avatar position, the viewpoint orientation, and the cursor position.

F. Collisions

The collision state of the participant's avatar with the environment should be recorded at each frame. A collision is detected when the avatar is in contact with one or several objects and that the participant's input leads the avatar to move towards them.

Using this information, we can then analyze the total number of frames where there were collisions, the percentage of frames where there were collisions, or the number of collisions divided by the total traveled distance.

G. Other Relevant Details

In order to simplify the later analysis of the data, all the collected information should be formatted into a text file in a tabulated manner, in order to allow easy import into spreadsheets.

Also, all the data should be organized in order to support empirical evaluation of participants (i.e. formal experiments with human subjects). Therefore, additional information should be provided to the system in order to further automate the data collection process. This information could include the number of practices and trials to do, as well as the instructions to the participants.

H. Experimental Procedure

Independently from the chosen experimental design (within-group or between-group), the experimental procedure follows several steps.

First, for each experiment, several participants will test one or several different conditions (here the travel techniques), each requiring the completion of one or several tasks.

Second, for each combination of condition and task, the participant will complete a *testbed run* consisting of a series of p practices (where p is an integer greater than or equal to zero), followed by t trials (where t is an integer greater than zero).

Before each practice and each trial, a dialog box will appear on the screen to display the instructions to the participant. Once the participant acknowledges the understanding of these instructions by pressing the "OK" button or the Enter (or spacebar) key, the next practice or trial will begin.

Each practice and trial is preceded by an audio countdown of three beeps separated by one second. This is done to help focus the participant's attention on the task that will follow. Once a practice or trial is completed, all the collected data is recorded in a text result file on the computer. The data is tabulated to allow easy import by spreadsheet software for latter analysis.

When the last trial ends, a dialog box containing instructions to indicate the end of the experiment for the current condition is displayed. If several conditions or tasks are to be tested, the experimenter can simply start another testbed run to be completed by launching another content file that describes the new experimental parameters.

III. IMPLEMENTATION

I. 3D Scene Viewer

In order to implement the testbed, we chose to extend the capabilities of Demotride, a custom built 3D scene viewer that supports the VRML/X3D international standard formats for content files that describe the virtual scene and travel interface [16,17,18]. Apart from the ability to support new interaction techniques, one benefit of using this viewer is that it offers the possibility to control the maximum rotation speed when velocity control is used. This capability is crucial for the reproducibility of the experiments.

Using the classical VRML encoding syntax, we implemented the ability to record experimental data in the form of a new node called "Experiment". Since this capability is not included in the VRML/X3D standards, we added it to the viewer.

J. 3.2 The "Experiment" Node

The new "Experiment" node has the following syntax:

practiceInstructions	""	exposedfield	SFString
trialInstructions	""	exposedfield	SFString
finalInstructions	""	exposedfield	SFString
nbPractice	1	exposedfield	SFInt32
nbTrial	1	exposedfield	SFInt32
nextStep		eventIn	SFTime

practiceInstructions: This field specifies the text to display in a dialog box before the beginning of a practice. The participant will have to press the "OK" button or the Enter (or

spacebar) key once the instructions are read, in order to proceed to the practice.

trialInstructions: This field specifies the text to display in a dialog box before the beginning of a main trial. The participant will have to press the “OK” button or the Enter (or spacebar) key once the instructions are read, in order to proceed to the trials.

finalInstructions: This field specifies the text to display in a dialog box at the end of the main trials. The participant will have to press the “OK” button or the Enter (or spacebar) key once the instructions are read, in order to complete the trials related to the current condition.

nbPractice: This field specifies the number of practices that the participant will have to complete.

nbTrial: This field allows to specify the number of trials that the participant will have to complete.

nextStep: This eventIn indicates to the system that a particular trial or practice has been completed and that it should proceed to the next step, i.e. a practice, a trial or the end of trials.

In a typical use, an object associated with a Collision node is located at the end of the travel path and when a collision occurs with the avatar, the collideTime event generated is routed to the nextStep eventIn of the Experiment node.

The recording of the data in the result file is done only once the whole treatment is completed. The file name has the following syntax:

[ContentFilename]_[T|P][number]_YYYY-MM-DD_hh-mm-ss.txt

Depending whether the completed task was a trial or practice, the T or P letter is chosen respectively after the ContentFilename. For example, for a ContentFilename of C1.wrl, the result file recorded after the second trial could be:

C1_T2_2008-03-19_10-04-12.txt

The time representation has been chosen to be compatible with the international standard for numerical representation of times and dates [19]. This format allows easy chronological sorting in a computer folder.

K. Structure of the result file

The data collected during the empirical evaluation of a particular combination of task and condition, as well as for a particular participant and a particular practice or trial, is stored in a result file. This text file has several components as described hereafter.

The data collected for each frame is stored on a single line of the text file with the different pieces of information separated by tabulations.

These pieces of information correspond to those identified by the requirement analysis, i.e.:

Time

The timestamp indicating the moment where the data was collected, the time reference ($t=0$) being the start of a task.

Avatar Position

The absolute (x,y,z) position of the avatar’s center, at the level of the eyes.

Viewpoint Orientation

The absolute orientation of the viewpoint, expressed in quaternion coordinates (w,x,y,z).

Cursor Position

The absolute position of the cursor in the viewing window, expressed in pixel coordinates, starting from the upper-left corner.

Other Inputs

State of the different discrete inputs stored in a bitwise representation, for example, mouse button currents state (pressed or released). The use of a bitwise representation allows to represent and analyze multiple simultaneous inputs, by using bitwise operators. For example, a value of zero indicates that no input was happening at that particular moment, while a value of 1 indicates a left click of the mouse, a value of 2 indicates a right click and a value of 3 indicates both a left and right click.

Collisions

The collision component is represented by a boolean value, equal to one if a collision is detected and zero otherwise.

L. Post-Processing

Once an experiment is completed, the data stored in the result files can be analyzed using spreadsheet software. By using script programming, spreadsheets can be used to extract all kind of information from this amount of detailed data. For example, it is possible to extract the total traveled distance by adding the distances that separates positions at each frame. Another possibility is to draw the traveled path.

The high level information such as task completion time or total traveled distances can then be processed to achieve the desired statistical analysis, such as an analysis of variance, by using statistical tools.

IV. DISCUSSION

This paper reports the result of our practical experience in the design and implementation of a testbed software for the empirical evaluation of 3D travel interfaces.

We found that such a tool increases significantly the efficiency of the empirical analysis process given the large amount of data that is produced. This provides the ability to access not only the high level data, such as task completion time, but also finer degrees of detail when required. This is useful, for example, when one wants to draw the path followed by the participants in the virtual environment or to replay the travel.

In practice, we used this tool successfully to assess the effectiveness of 3D travel techniques for virtual walkthroughs in desktop environments [20]. These preliminary results indicate that the testbed described here is well suited for this kind of empirical research.

In order to extend further the automation of the data analysis, one possibility could be to record the collected data directly in a database file for later postprocessing.

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