EXPERIMENTAL SET-UP FOR HAPTIC INVESTIGATION OF REAL AND VIRTUAL ENVIRONMENTS

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The interfaces that are used when connecting human and machine systems together are the human senses. These interface systems can be called bio-mimetic systems in that they are designed to respond to reactions and sensations of a biological system – the human operator. Various systems exist, that provide information to the human senses of sight and hearing. Audio and video systems have been perfected so that it is now possible for a user to wear small devices, which will allow a user to see and hear various forms of information. Systems exist currently and others are being further developed that interface with a third human sense, the sense of touch. These systems are called haptic systems or simply haptics. The inclusion of haptic systems allows the creation of fully immersive environments that can provide a user with the three major inputs of visual, auditory and haptic information. These systems can be used for virtual reality and telepresence applications.

1. INTRODUCTION

Haptics is a recent enhancement to virtual environments allowing users to "touch" and feel the simulated objects with which they interact. Haptics is the science of touch. The study of haptics emerged from advances in virtual reality. Virtual reality is a form of human-computer interaction (as opposed to keyboard, mouse and monitor) providing a virtual environment that one can explore through direct interaction with our senses. To be able to interact with an environment, there must be feedback. For example, the user should be able to touch a virtual object and feel a response from it. This type of feedback is called haptic feedback.

In human-computer interaction, haptic feedback means both tactile and force feedback. Tactile, or touch feedback is the term applied to sensations felt by the skin. Tactile feedback allows users to feel things such as the texture of surfaces, temperature and vibration. Force feedback reproduces directional forces that can result from solid boundaries, the weight of grasped virtual objects, mechanical compliance of an object and inertia [6].

Technological progress enables to realize haptical perceptions of virtual items. These computer-aided haptical perceptions are subject to several restrictions in comparison with haptical perceptions of real objects: e.g. there are no perceptions of temperature or pain being simulated by the haptic-device. Furthermore the haptical perceptions are reduced in grabbing, holding, moving and recognizing the surface quality of the objects due to the construction of the device because the transmissions of perception are simulated by a kind of pencil. This corresponds approximately to a haptical perception in real situations with only one finger. So the movements of the fingers and the hand, which are very important for the haptical recognition of objects (Goldstein, 2002, S. 550ff), are extensively reduced. This results in a restriction of exploration movements, which are necessary for the haptical recognition of objects, like moving the fingers back and forth on the surface, embracing of objects and following the outline with several fingers. Especially the embracing of objects is affected by this restriction. But Ledermann & Klatzky (1987, 1990) could show that mainly the following of the outline is used to perceive the precise form of objects, and moving back and forth is used to judge the texture (in the psychological sense).

Consequentially the question is, if computer-aided haptical perceptions correspond to the qualities of perceptions of real objects.

2. OBJECTIVES OF THE STUDY

First of all only the haptical perception of weights should be examined in this analysis. The operationalisation comes to pass with the weight-threshold and several psycho-physiological parameters.

For the identification of the weight-threshold with real and virtual stimulus-material the constancy-method (Fechner, 1860) was used, because it is the most precise method to identify thresholds (Goldstein, 2002). In the constancy-method a row of cube pairs with various differences in weight is presented to the test persons. The cube pairs with these differences in weight are arranged by chance. There are six dissimilar stimuli of differences in weight presented ten times. The largest stimulus of difference is absolutely above the threshold, so the participants can realize the difference for sure. The smallest stimulus of difference is definitely below the threshold, so that the observers do not detect it under any circumstances. Usually the intensity of difference, which is detected at the half of the trials, is defined as threshold.

It is supposed, that the two possibilities of haptical perception do not differ when the psycho-physiological reactions of real and virtual perception of weight are the same. For the psycho-physiological parameters the following variables are chosen: heartbeat frequency, variability of the heartbeat frequency, muscular tension in the neck area, breath frequency and breath volume, level and reaction of skin conductivity, pupil diameter and variations of the pupil diameter and of the eye-movements.

3. GENERAL METHODS

Analyzing the comparison between real and virtual perception of weight, the virtual and real thresholds of difference in weight should be determined by two threshold-experiments. In the time of the determination of the virtual and real thresholds of difference, the psycho-physiological reactions of the test subjects are recorded additionally, so that the involuntary reactions also can be judged.

3.1. Sampling procedure and description of sample group

All participants of the analysis have been recruited by notice published on news boards and notices in lectures. The participation at the experiment was paid. All test persons participated at both of the haptical experiments. The test persons did not know the conditions of the experiment in advance. The sample group consisted of students of the FH Vorarlberg. In the sample group there were students of the study courses media design, informatics and social work.

3.2. Experimental setup

Both experiments took place at the laboratories of the Usercentered Technologies Research Lab of the University of Applied Sciences Vorarlberg (Austria). At the threshold definition with realistic stimulus material the test persons sat on an office chair at the table with a distance of 40 cm. On the table the stimulus material was set up. They had the possibility to move their non dominant hand, which was connected to measure their electro dermal activity, and to place it in a comfortable position on the table or on the backs of the chair to avoid muscle tenseness, which could harm the movements.

At the threshold determination with virtual stimulus material the subjects sat on an office chair with a distance of 60 cm to a 15" computer screen. The haptical device with control stick was positioned on the side of the dominant hand. Same as at the experiment with the real stimulus material, the none dominant hand could be placed comfortable.

3.3. Stimulus material

The stimulus material has to differ in realistic and in virtual material. The virtual material is distinguished to experience the objects via computer.

3.3.1. Virtual stimulus material

The virtual stimulus material is represented on a computer screen. There are two three dimensional, red cubes. Each of them has a length of 6 cm on the screen. One cube simulates constantly the standard weight of 300 grams, the other one varies between 300 and 325 grams in steps of 5 grams. Every weight stimulus is represented ten times. The haptical interface is able to simulate reset forces and other external influences e.g. by means of electrical motors, electricorheoligcal attenuators or vibroactors. It is possible to procure invisible information. They also make it possible to bump at virtual objects or experience the weight of them in the computer generated virtual reality (VR). As a tool, a pen like control stick is used to move a tennis ball like cursor which enables to perceive objects haptically presented on the screen. With this cursor it is possible to move the cubes, bump into them or experience the weight of a cube, if you move the cursor under the cube and lift it up.

3.3.2. Real stimulus material

The real stimulus material consists of red squares with the same edge length like the virtual cube (Fig. 1). The cubes are made up of 220g/mm2 strong Paper filled with sand, in order to match the required weight. The standard weight consists of 300 g, whereas a set of different cubes used for the comparison had a weight of between 300 and 325 g. Every single cube had a difference in weight of 5g compared to the next. To provide the same circumstances while testing the real and virtual cubes, there was constructed a kind of shovel with the help of a 3D prototyping printer. The handle of shovel should thereby allow the test persons to hold it like a pen in exact manner as the handle of the haptic device. Both handles have the same size and form avoiding so any variation in perception related to differences in form, size and handling.

Figure 1. Real stimulus material and its handling

3.4. The experiment

To ascertain the weight threshold with real and virtual stimulus material, the constancy method [1] was used because it shows to be the most accurate method for acquiring thresholds [2]. The experiments took place on two days with an average interval of four weeks. After attaching the measurement instruments, the experiments were accomplished with real and virtual stimulus material. Therefore the test persons had to judge two cubes by their weight difference.

On the first date, ten cubes were placed on a wooden construction so that the test persons could easily lift the cubes with a shovel which was constructed right for this purpose. From the left to the right the cubes had to be evaluated by differences in weight whereas two nearby cubes built a pair of a standard weight that stood the same all the time and a reference weight that varied randomly. In doing so, the standard weight was always standing on the left and the reference weight on the right position. The test person were asked to roll with their office chair from one pair of cubes to the next pair of cubes to ensure a correct position right in front of the cubes to be lifted. After evaluating all five pairs another palette of five cube pairs were introduced. After evaluating all ten pairs of cubes the test persons had a break so that they were not too overextended in concentration and haptic perception. This process was repeated five times, so the test persons had to evaluate 60 different pairs totally concerning differences in weight. The reference weights were assigned to the different palettes at random with use of the Excel random generator. The palettes themselves were also given to the persons randomly. To determine when exactly the test persons realize a difference in weight a Motion Capture sensor was attached to the shovel that registered height differences. The sensor was calibrated to a basic value of zero at the level where the cube was resting on the palette. When the shovel with the sensor was lifted the sensor provided values above zero and vice versa. This is based on the fact that the test persons experience differences in weight at values higher than zero that means levels higher than the palette.

On the second date the threshold examination was arranged with virtual objects using simulated haptic weight determination. Two red cubes of same size are displayed on the monitor in a three-dimensional environment side by side. The test persons had to steer a cursor-like object with the crayon-like control stick of haptic device (Phantom, USA) under a cube and lift them to experience a sense of weight. Like in the real tests, the left cube had a standard weight of 300g and the right one served as reference weight. After judging the differences in weight a new pair of cubes was displayed. There was a five minute break after ten completed pairs to avoid adaptation of perceptions or low concentration. In this manner 60 cube pairs were judged in total by differences in weight.

3.5. Recording data

The test consists of recording the perceived differences in weight, peripheral physiological bio-signals and the collection of altitude differences of the dices. In the following, the data collection gets described more detailed.

Collection of differential threshold

The observed differences in weight were communicated by the test person to the recorder in the experimental laboratory with the help of a microphone and were immediately registered in a protocol. This is about a dichotomous variable presuming these characteristics: "difference of weight perceived" or "difference of weight not perceived".

Peripheral physiological bio-signals

The peripheral physiological data were recorded on the Vario-Port (meditec Gmbh, Germany) with the help of software developed in the University of Applied Sciences, Vorarlberg. The impact of motor activities during lifting the cube was ignored, because movements were quite the same in both studies and besides the impact less important than commonly assumed [3]. Finally EKG, EDA, EMG, breathing activity and movements of the pupil were recorded.

The psycho-physiologic signals were sampled with 50 Hz. For the EKG a sensitivity of 0,75mV and sampling frequency of 50 Hz was chosen. The electrodes were positioned on the upper third of the sternum and in height of the sixth rib.

For the EDA recordings, a sampling rate of 50 Hz was used. The electrodes were attached on thenar and hypothenar of the non-dominant hand of the test person. The dominant hand was used to operate the shovel and the control stick respectively. To control the artifacts the EDA was recorded parallel to breathing with use of a pressure sensor above the belly button. The sampling sensitivity was adapted individually so that the signal preferably filled the complete recording area of the BioGRAPH-system when the test person was deeply breathing.

4. CONCLUSION

New three-dimensional in- and output devices, which enable the perception of the natural environment although performed by means of a computer, shall be deemed nowadays as synonym for virtual reality. The user is connected with sensors that are built to navigate and interact in the virtual world. Interaction which allows to percept objects haptic in real time can improve the grade of immersivity.

Although some advances are still needed, the fundamental technologies are being developed to provide useful haptic systems. In this paper, an experimental setup for haptic investigation of real and virtual environments is presented. To test if computer generated environments are percepted exactly in the same way as real environments are, the computer generated and the natural weight differences should be determined on the basis of two weight-threshold experiments (based on the experiments of Fechner). During these experiments the psycho-physiological reaction of the test person is recorded. If the virtual and real weight-threshold differences and both of the psycho-physiological records match together, it can be assumed, that the haptic perception is equal. In addition, designs of the virtual and real environments of the research experiment are presented.

5. REFERENCES

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