ERGONOMIC AND TECHNICAL EXAMINATION OF VIRTUAL ENVIRONMENTS

Theses of doctoral (PhD) dissertation for public discussion

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CONTENT

ACTUALITY AND IMPORTANCE OF THE RESEARCH TOPIC

Nowadays, in a growing number of areas of life, a Gamification approach is used to solve certain problems and to popularize certain activities [10, 11]. Of course, the field of application cannot be absent from the field of application [2, 8, 14, 18, 19, 29].

Virtual Reality (VR) technology provides a unique toolkit for effective rehabilitation, whether phobia treatment or motion therapy for stroke patients [24, 27, 28]. Its usefulness is significant, the therapy can be implemented in a function-central, goal-oriented and motivating environment.

Unfortunately, stroke has now become one of the most common diseases. In Hungary, stroke is one of the most common causes of death and the most common disability-causing illness. This requires the incorporation of modern technology tools into effective stroke therapy.

Defects in color vision are often neglected because most people do not consider it a serious problem. Approximately 15% of the population is affected by different color vision errors [15]. A common mistake in computer applications is the inadequate combination of background and foreground colors, which can render web pages, software, games, users with color vision errors unusable.

The role of virtual reality-based "serious game" software solutions in post-stroke rehabilitation is also important. Several frameworks, even in the home environment, have been developed in recent years worldwide [1, 5, 6, 7, 9, 12, 13, 14, 15, 17, 20, 22, 23, 25, 26, 30]. Unfortunately, many of them did not spread, did not replace the hopes. The main reason for the failure of these rehabilitation projects is the experience of previous projects that patients and supporters and nurses find it difficult to use new IT tools, difficult to personalize therapy, and patients lose motivation [29].

In my dissertation I present my researches and results on the visualization of virtual environments on the one hand, and on the other hand, a solution that supports motion rehabilitation applications that are already in operation and will be developed in the future, so that in the rehabilitation the movement therapy can be fully adapted to the patient's needs, condition to ensure a sense of success, to maintain patient motivation.

AIM OF THE RESEARCH, MOTIVATION

Visibility, spot-on, color-optimized interface - on the one hand due to the problems of vision, as a side effect of stroke, because of visual problems, on the

other hand, because of the large number of visually impaired people in the population related to digital technologies in general.

It was an important factor in my research to investigate the spatial representation in rehabilitation applications and games [21].

Deficiencies in color vision may include acquired illnesses or inherited diseases. Unfortunately, stroke leading to death worldwide, for example, in the United States, nearly 800,000 people fall victim each year - every 20th is fatal [4]. Approximately 610,000 of these cases received stroke for the first time; It is a multiple of repetitive cases of 185,000 people. According to data from ophthalmologists, optometrists, 10% of the male population lives with a color vision defect or is completely colorless. This data indicates a statistically significant number of subjects at the incidence of stroke.

In the digital worlds and in virtual environments, I have focused the visibility tests on the web display area because this area is where the highest number of target audiences reaches the content that appears. In all cases, color accuracy studies are an important question as to how we look at color fidelity. There are so many contents on the Internet that although I could have chosen the most frequently viewed pages, I visited most often photo galleries, probably I would not have been able to perform an exact examination in the absence of reference data. However, I was in a very fortunate position when it came to light that in the LED4ART - High Quality and Energy Efficient LED Illumination for Art project [16] between 2012 and 2014 is our research laboratory, the Virtual Environments and Light Science Research Laboratory have been given the opportunity to modernize and design the interior lighting of the Sistine Chapel. In the Sistine Chapel, under the guidance of Professor János Schanda, colorimetric measurements of the frescoes of the chapel were made, which meant that I had a reference measurement of an original environment that could be used to carry out serious research on digital reproductions on the Internet.

Nowadays, the digital reproduction of many works of art and paintings is available on the Internet, either in a personalized and uploaded version, or on their own official websites of galleries and museums, in many cases in online galleries for their own virtual museum tours. Searches from the Internet are the result of a variety of sources, when Google or any other search engine searches for works of art, and the number of hits is ten thousand. The visual quality of the results, at first sight, shows a very large dispersion, either in image size, image resolution or simply in terms of appearance. The question is, therefore, is there a significant difference between the digital reproductions of original works from several online databases and the original works of art. The purpose of my studies and measurements was to discover the causes of perceived differences.

The other area I studied was to analyze the computer interactions of users. There are also a number of initiatives in the health sector [11], mainly in the field of rehabilitation where exercise is used. There are "serious" games

(development games, their original English name "serious games") that can be used to supplement physical therapy because they use motion elements to control them that the therapist recommends. In these software, the patient's movement is monitored through an optical device and indicated when the exercise is done properly. There are applications where the user is placed in a virtual reality, for example, handling his phobia or reducing his frustration with the rehabilitation procedure.

Kinect Control allows users to interact with the program without any tools to be handled, using only their own body, motion patterns, and gestures, which also enhances the user experience. My research is motivated by the fact that the difficulties of the device can be eliminated and, for example, Kinect or other similarly optical sensors can be successfully applied at any stage of the rehabilitation therapy.

APPLIED TOOLS AND METHODS

Test materials and method used for testing of color reproduction:

For the examinations, four frescoes were measured for the work by the researchers of the Virtual Environment and Light Science Laboratory at the Sistine Chapel frescoes.:

- Cosimo Rosselli: Crossing of the Red Sea
- Cosimo Rosselli: Tables of the Law
- Sandro Botticelli: Temptation of Christ
- Michelangelo Buonarroti: Last Judgment

For each of the four frescoes I used three sets of input data:

- CIELAB data provided by the Vatican, which refer to D50 illumination, CIE 2 ° viewing angle, were my reference data during the tests;
- directly measured reflection spectrum data on selected frescoes;
- digital reproduction (soft-copy) from four different Internet sources, displayed on a calibrated LCD monitor.

For each fresco, I chose the details of the color patches for the measurements. The selected samples were measured with an X-rite Eye-One (i1) spectrometer at 10nm in a wavelength range of 380 nm and 730 nm. For colorimetric calculations, the data recorded in 10 nm increments were converted to a 5 nm scale, because it was in line with the laboratory's previous practice and work, but no measurement range correction was made because such information was not available for the Vatican's measurement data, all data were treated in the same way and since the measurements are reproduced in different media, the measurement range correction would not have provided much more insight into the problem..

Due to similar considerations, the evaluation of the measurements was performed in the CIELAB color space and I did not use more sophisticated colorimetric calculations, but the systematic measurement errors are negligible because the measurements were always done with the same calibrated measuring instrument.

For digital reproductions, the white point peak was considered to be R = G = B = 255, which corresponds to the 5352 K correlated color temperature. For the other spectra I used the D50 white point, as the information indicates that the Vatican CIELAB values were also calculated with this reference illumination. Calculations were performed using CIE 1931 2 ° color matching functions.

In the course of my research I determined the degree of measurement uncertainty and characterized the reliability of the series of measurements by statistical tests. I have tested the repeatability of the measurements, as well as the homogeneity measurement for the calibrated publishers. After that I performed an examination of the original and digital reproduction of the scenes, and then I carried out measurements on the display of different browsers, which means 1100 measurements.

Test Material and methods related to user interaction:

For the tests, I used 7 different motion patterns for motion therapy and two VR games with a 16-person test group, which means 224 sets of motion data, each data set containing at least 10 complete motion cycles, i.e. 2240 motion cycles.

I investigated whether data coming from the Kinect sensor should be cleared because these data contained incorrectly measured data and values that were not measured by the sensor, but only estimated values. Then I examined whether the result of the motion cycle identification process depends on the processing algorithm when processing the motion description set. Based on the data sets I made the reconstruction of motion patterns in 2 and 3 dimensions. After reconstructing, real-time detection and classification of motion patterns was investigated, and an application was created to visualize the motion record data set, to display previously recorded movements.

NEW SCIENTIFIC RESULTS

In the context of ergonomic and technical testing of virtual environments, I have produced the following results based on application-related visibility considerations:

Thesis Group I: Examination of color fidelity in Virtual Environments

I.1. thesis: Significant differences of ΔE * >= 3.2 between the colors of the real world's original objects and their color reproduction.

My research has shown that there is a significant difference in color fidelity between the original real objects and their digital reproductions.

I.2. thesis: The source of the discrepancy found in Thesis I.1 is complex. One reason is the different display technology of browsers, which is significant in color rendering, ΔE * min = 4.49 and ΔE * mean = 17.33 deviations.

Measurements show that these differences are not due to measurement errors and are not random variations but are caused by a lack of color space information for processing, decoding and displaying different image compression and decoding techniques, incorrectly applied or simply digital reproductions.

Not only is it essential for people with color vision problems, but it is also important for intimate visionary people to have the right color information displayed and not to allow color coding for the sole information to be communicated.

Recommendation for partial solution of the problem:

When processing digital reproductions (digital camera, scanner), make sure the image maker does not miss the color space information or delete the EXIF information from the JPEG images.

In the case of digitally stored reproductions, as little compression as possible should be minimized by storing information.

Related own publications: S1, S4, S6, S8, S10, S14, S20, S24, S31, S35, S39, S46.

Of these, 7 were published as the first author.

I summarize the results of user interaction and the usability aspects of virtual environments in the following theses:

Thesis Group II: Motion Descriptive Data Analysis, Motion Pattern Recognition, Reconstruction and Visualization

2.1. Thesis: If modern input devices do not provide proper interaction in motion rehabilitation applications, they cannot be used in daily practice, and their market introduction is not realized.

The experience gained in the StrokeBack[17] project, as well as the experience gained at the National Institute of Medical Rehabilitation in Hungary, confirms that the continuous success and motivation of the user is an important condition for the practical application of new technologies and developments.

Recommendation for a solution:

There is a need to develop a method that ensures the continuous success of the user in Kinect's sensory rehabilitation applications in a real-time process.

Related own publications: S7, S15, S18, S19, S21, S22, S28, S29, S30, S32, S36, S40, S42, S47

2.2. Thesis: Although the motion description data from the Kinect sensor is not error-free, it is also suitable for further real-time processing without prior error correction.

My performed examinations have shown that the motion description data that can be extracted from the Kinect sensor contains estimated values when the sensor loses contact with the user and also contains incorrectly measured coordinate data. In the course of the investigations it was concluded that the preliminary correction of the data is not necessary, because during the later processing the deviation resulting from these errors in the recognition and classification of the gestures does not result in a significant difference either in the negative or in the positive direction. In an optimal environment without error correction, the detection ratio (R_f) is Rf = 97%, with Lagrange interpolation correction Rf = 93%, after 9th polynomial matching R_f = 97%, which means a +/- 1 correctly recognized motion for a sample of 30 cycles.

2.3. tézis: The method of processing motion description data influences the efficiency of processing and gesture recognition, thereby maintaining the user's sense of success.

My studies have shown that in the Kinect sensor, different methods of processing skeleton-associated motion descriptor data showed different results in recognizing gestures.

Recommendation for a solution:

Using methods developed simultaneously with research, the Distance Vector Based Gesture Recognition **(DVGR)**, and the Reference Distance Based Synchronous/Asynchronous Movement Recognition **(RDSMR/RDAMR),** gestures used by users to control applications in therapeutic applications in rehabilitation applications can be recognized in real time with high accuracy.

2.4. Thesis: The classification of the motion pattern requires the use of a real-time classification method adapted to the user's specific needs.

Based on the experience gained during the research and the review of the literature, the misidentified movements and expectations of inadequate level of movement coordination in applications controlled by Kinect have led to a feeling of failure by users and have lost motivation for further use.

Recommendation for a solution:

Simultaneously with the research, I developed a real-time process, the Real-Time Adaptive Motion Pattern Classification (RAMPC) to support Kinect's sensory control of motion-rehabilitation development games, applications that, in response to user needs, based on relative reference base generation, define controllable parameters acceptance range for accepting user gestures. This method makes Kinect sensor-driven motion rehabilitation applications applicable to all phases of therapy, so it will not cause any failure in the exercise, even in the case of a high degree of motion limitations and will therefore most likely maintain the user's ongoing motivation.

2.5. Thesis: The post-reconstruction and visualization of motion patterns can be used to visualize therapeutic exercise tasks in a home-care environment and in a telemedicine environment in a form that can be easily understood by healthcare professionals.

During my research, it has been proven that VR-based or conventional motion therapy under personal supervision is more effective, the degree and direction of the patient's development is more controllable because there is not enough and meaningful information on performing rehabilitation practices in a telemedicine environment in a home environment and it may be costly to transmit large amounts of data on the communication channel.

Recommendation for a solution:

At the same time as the research, I realized the **Re (al) Play!** - motion pattern reconstruction application. For Kinect sensory motion rehabilitation applications, motion description data can be stored in a file and stored in plain text format. The transmission of this small content on the Internet does not generate significant costs.

Files containing motion patterns (exercise data) can be visualize with a reconstructive 'Re (al) Play!' application to the therapist. In the application, it is possible to replay the motion pattern and to display the range of motion of the body parts involved in the observation in the selected plane of the space as a function of time on a graph. Based on this two information, the therapist gets a complete picture of the patient's development and the effectiveness of the exercises.

Additional own publications related to Thesis Group II.: S2, S12, S13, S23, S25, S27, S34, S37, S43, S44, S48, S49, S50

The ***5*** The publication of the results related to the ***2.1, 2.2, 2.3, 2.4*** sub-theses is currently under review (At the time of submission of the dissertation, the first author, impact factor publication was published: S [52]).

RECOMMENDATIONS FOR FUTURE RESEARCH DIRECTIONS

Based on the results of the research, it requires further research in the field of spatial displaying to determine if there is a possibility to develop a fix for the current image compression process that will allow for more accurate image information recovery.

Another question about user interaction related to virtual environments is whether the improvement of the user's movements can be predicted by a predictive algorithm, and based on such a prediction, the base can be generated from the previous motion descriptors, the reference to the **DVGR / RDSMR / RDAMR / RAMPC** algorithms. It is also necessary to further investigate whether the width of the adaptive acceptance range can be limited based on previous motion description patterns when classifying motion patterns.

In the field of virtual reality-based rehabilitation applications, the spread of mobile devices cannot be ignored, and the use of humanoid robots is a questionable area that raises further questions. A more far-reaching aspect of the use of mobile devices is the field of communication and communication protocols, because today's technological development is basically aimed at improving cloud-based storage and cloud-based computing capacity utilization.

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