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Postupak ocjene doktorskog rada

DOKTORAND/ICA:	Ana Agić, mag. ing. techn. graph.

NASLOV RADA na hrv. jeziku:	Poboljšanje korisničkoga iskustva u virtualnoj stvarnosti postavljanjem parametara oblikovanja scene i načina kretanja
NASLOV RADA na engl. jeziku:	Enhancing the virtual reality user experience by setting scene design parameters and locomotion techniques

SAŽETAK:

U ovoj doktorskoj disertaciji glavna tema istraživanja je virtualna stvarnost i neki njezini aspekti koji utječu na subjektivni doživljaj kibermučnine. Kibermučnina (engl. Cybersickness) je neugodna posljedica koja se javlja kod nekih korisnika sustava za virtualnu stvarnost u obliku simptoma mučnine, glavobolje, vrtoglavice, znojenja, zamora očiju i slično.

Disertacija je podijeljena u ukupno 11 poglavlja, od kojih su neka teoretska i daju uvid u teoriju virtualne stvarnosti, njene povijesti, tehničke aspekte i mogučnosti primjene u različite svrhe. Također, poglavlja koja opisuju istraživanja u kojima drugi istraživači kroz teoretske aspekte i istraživačke studije daju svoj doprinos razumijevanju ove tehnologije koja je u zadnjih nekoliko godina doživjela svoj ponovni uzlet. U vezi s time, dan je i pregled mogučnosti i načina evaluacije jednog od aspekta korisničkog iskustva kroz subjektivnu metodu anketama i upitnicima, kao i kroz objektivne metode mjerenja fizioloških promjena kod čovjeka koje nadopunjuju uvid u istraživanja.

U okviru ove disertacije napravljena su i tri istraživanja, koja su opisana u istraživačkim poglavljima. Prvo istraživanje je bilo uz pomoć subjektivne metode ankete i objektivne metode elektroencefalografa (EEG) utvrditi utjecaj medija (2D/3D) na kibermučninu. Istraživačka pitanja, metodologija i rezultati su opisani u podpoglavljima vezanima uz to istraživanje i mogu se vidjeti u prikazu na „Slika 1“. Drugo istraživanje je usmjereno na istraživanje utjecaja brzine kretanja u VR-u na kibermučninu, također evaluirano subjektivnom i objektivnom metodom (uređaj za mjerenje elektroprovodljivosti kože). Slika 1 također ukratko prikazuje istraživačka pitanja, medodologiju i rezultate, kao i u detaljnijoj mjeri podpoglavlja vezana uz to istraživanje. Posljednje istraživanje u ovoj disertaciji je istraživanje tri različita načina kretanja u kombinaciji sa dvije varijante osvjetljenosti scene. Korištena je jedna subjektivna metoda evaluacije i dvije objektivne metode (mjerenje pulsa i EEG) evaluacije jednog aspekta korisničkog iskustva u virtualnoj stvarnosti. Na „Slika 1“ mogu se vidjeti istraživačka pitanja, metodološki pristup i zaključci, dok je detaljni opis ovog istraživanja u odgovarajućim podpoglavljima.

Disertacija završava sa zaključkom u kojem su opisani svi relevantni rezultati istraživanja, popisom literature te dodacima.

Ključne riječi: virtualna stvarnost, iskustvena kvaliteta, kretanje, dizajn scene, kibermučnina.

ABSTRACT:

This doctoral thesis focuses on methods for enhancing user experience when using virtual reality (VR) applications. Virtual reality is not a new technology, although in the last five years it has witnessed market growth, with relatively affordable prices making it possible for users to purchase such devices for home use. The availability of the technology is awakening people's creative side, fostering the creation of a variety of games, demos and experimental works becoming available on the market. One of the major problems that occurs when using a VR device is the feeling of discomfort and nausea known as cybersickness [1]. Cybersickness results from the mismatch between different sources of user's sensory input, primarily oculomotor, vestibular and proprioceptive system [2]–[5]. The user may experience a feeling of confusion, because she/he is moving in a virtual world, but not in the real world. The feeling one experiences is similar to sea sickness or travelling illness [6]. Symptoms include dizziness, sweaty hands, postural instability, headache (which can occur afterwards), eye strain and others [7]–[10].

The next step when addressing these problems that arises as a negative consequence of conflicts between the oculomotor and the vestibular system is the design of the system in which the user experiences the virtual world [11]. This refers to the design of the surroundings, and more importantly the techniques for navigating (or moving) through the virtual world, also known as locomotion techniques. Nowadays, users are most accustomed to the classic methods of moving around in virtual environments (such as games) with a mouse and keyboard, or with a

joystick in the case of game consoles. Unlike those classic gaming systems, VR devices use controllers which are held in the hands and used for interaction and movement in a three-dimensional space. There are many locomotion techniques, some of which feel more or less natural, some are more or less intuitive and some are more or less creatively executed. Also, it should be taken into account that the user is moving around the virtual world and that his/her position is constantly being recalculated and his/her environment is constantly changing.
In this this research (with the intention to reduce the feeling of cybersickness), various studies were conducted in which the influence of media (display of graphic content on different (2D and 3D) screens) on cybersickness, secondly the influence of speed on cybersickness and lastly the influence of locomotion techniques and scene illumination on cybersickness. The user experience is investigated and evaluated using both objective and subjective metrics. The need for objective metrics is due to the fact that subjective assessment by surveys and questionnaires does not necessarily provide comprehensive input on the user experience, hence objective metrics may be used to provide further insights and information. Furthermore, in case when subjective evaluation is not available for any reason, then an estimation of experiential quality can be made on the basis of objective metrics (if it is established that these metrics correlate with subjective assessments). In accordance with that, three devices for collection of objective metrics are used, namely a device for measuring electrodermal activity, an electroencephalogram (EEG) device which measures brain activity and may indicate changes in human states of relaxation on stress events, and a heart rate monitor.
The purpose of using objective and subjective metrics during research is to investigate potential statistically significant differences and correlations between certain variables in order to point out positive or negative consequences of the changes that have been tested in the research of locomotion in virtual environments. Such findings provide important insights when designing VR environments so as to enhance the user experience, which ultimately is the purpose of this research.
A study of cybersickness in 2D and VR conditions was the first study conducted. The results of the statistical processing of the survey show that there is a stronger subjective feeling of cyber nausea in virtual reality, where almost all tested variables showed a statistically significant difference compared to the 2D screen. The results of objective measurements with EEG show that the beta/alpha ratio of brain waves is highest in the VR environment and lower in the 2D environment. This result is in line with previous research and is associated with cybersickness [3], [5].
The use of subjective and objective metrics in the methodological approach are also the first scientific contribution of this dissertation.
In the second study, different speeds of movement in VR and the association with cyber nausea were examined. The subjective metrics of the survey show which are the dominant symptoms of cybersickness through all three tested speeds of movement. The most dominant symptoms are dizziness, blurred vision, and difficulty focusing on objects. A correlation was found between several tested variables where it can be concluded that female subjects are more uncomfortable in VR than male subjects. The objective metric (corresponding to electrodermal activity) did not show a statistically significant difference between the tested velocities. The most comfortable speed was the medium speed and the least comfortable was the fastest speed.
Establishing a correlation between subjective and objective metrics corresponds to the second scientific contribution of this dissertation.
The last study explored three different modes of movement combined with two different types of lighting used in the VR scene, and compared the various tested scenarios in terms of subjective and objective metrics.
Subjective and objective metrics were used, which corresponds to the first scientific contribution, and the establishment of correlations between subjective and objective metrics, which corresponds to the second scientific contribution. Subjective metrics showed more statistically significant results between the variables tested, such as dizziness, difficulty focusing on objects, sweating, nausea in the stomach, fatigue in VR, speed and mode of movement, and mean heart rate. No correlation was found between subjective metrics and the objective metric corresponding to heartrate. The third scientific contribution, the proposed method of reducing nausea by setting the parameters of scene design in virtual reality was achieved through the proposed locomotion method that caused the least cybersickness in respondents and through results that showed that most respondents prefer scenes with more brightness in virtual reality.
Key words: virtual reality, quality of experience, locomotion, scene design, cybersickness.

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