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Postural Stability Analysis In Virtual Reality Using the HTC Vive

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Abstract

Postural stability is an important measure for many medical diseases such as Parkinson. In the last years, research focused on using inexpensive and portable devices to measure postural stability, while the visual targets were physical objects in the environment. Sensing balancing boards were used to measure stance forces, while movements of the upper body were not taken into account. Within this paper, postural stability was measured using the HTC Vive. A variation of a virtual fixation point's distance was analyzed and compared to a reference condition with closed eyes. It is shown that body sway in the VR conditions is increased in the anterior-posterior and decreased in the medial-lateral direction.

Keywords: virtual reality, body sway, postural stability

Concepts: •**Applied computing** → **Health care information systems;** *Consumer health;*

1 Introduction

With the increased availability of virtual reality systems such as the Oculus Rift or HTC Vive, new therapy methods open up for persons with balance control problems [Wiederhold and Wiederhold 2005]. Postural balance of human beings depends on visual, vestibular, proprioceptive and somatosensory systems. It was shown that postural stability increases with smaller distance of real world visual fixation points and that self-motion becomes larger with closed eyes [Schulte-Pelkum and Nusseck 2007].

In virtual environments, balance studies are often related to symptoms of motion sickness, where the instability of subjects is used as symptom indicator. In a study by [Horlings et al. 2009], body sway was measured in VR and it was found that the instability in VR is similar as with closed eyes. The effects of VR on postural stability were investigated earlier, but mainly for visual-vestibular conflicts. Here, unequal movements were of interest, such as antidromic movements [Kesher et al. 2004]. [Nishiike et al. 2013] examined the effects of sensory inputs of visual-vestibulosomatosensory conflicts induced by VR on postural stability.

The limited field of view of the head-mounted display (HMD), noticeable latencies (174 ms) [Horlings et al. 2009], and a high measurement effort using various tracking devices made VR unsuitable for therapeutic applications. More recent research by [Epure et al. 2014] uses an Oculus Rift DK1 with a balance board and a Microsoft Kinect to measure the angle of sway. They concluded that this HMD used for these purposes leads to postural instability. [Chiarovano et al. 2015] use an Oculus Rift DK2 and a Wii balance board to measure the center of pressure.

The systems to measure postural stability mentioned above have shortcomings regarding field of view, tracking accuracy and latency. In addition, they are either too complicated to be operated by non-experts or too expensive to be privately used by patients. However, with new VR consumer products coming to the market, this conclusion needs to be reevaluated.

Figure 1: *The study setup*

2 Proposed Method

We use the HTC Vive with a display resolution of 2160 x 1200 pixels and a field of view of 110 degrees. With the system, it is possible to track the head position and orientation in a 4 x 4 meters range with a resolution in position of < 1 mm and in rotation of $< 0.1°$. Since the system does not require any other installation except the two lighthouses, the user just needs a balancing board consisting of rubber foam. The user stands on a foam balancing board and wears the HMD, which is again tracked using the lighthouse system (see Fig. 1). The virtual environment was designed in Unity and was kept very simple (see Fig. 2) in order to avoid any distortions of the measurements caused by varying complexity.

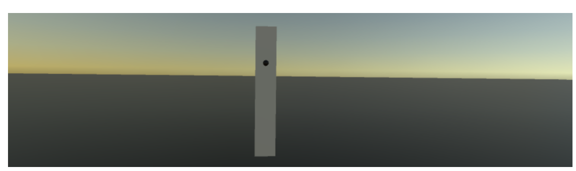

Figure 2: *Sample scene for stability analysis.*

2.1 User Study

5 healthy subjects in the age of 23 to 29 were given the task to stand still on a foam pad in 3 different conditions, always wearing the HMD: Eyes closed (EC), a target with a fixation point distance of 2500 mm and another distance of 6000 mm. Each condition was measured 3 times in a randomized order for each subject. The fixation point was a dark sphere 1800 mm above ground with 150 mm diameter inside a screen of 400 mm width and 2500 mm height. There was a visible horizon in the background. The HMD position

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vector was recorded and data was analyzed for a measurement duration of 1200 frames. The VR immersion per measurement was 40 seconds. In between the individual measurements, the subjects had a break of about 60 seconds. The recorded position data was transformed such that the average position was in the origin. As an indicator for the body sway, the root mean square values (RMS) of the position in anterior-posterior and medial-lateral direction were calculated.

3 Results and Discussion

The anterior-posterior (forth-back) body sway is shown in Fig. 3 (left) and the medial-lateral (left-right) in Fig. 3 (right). The error bars represent the standard deviation between subjects.

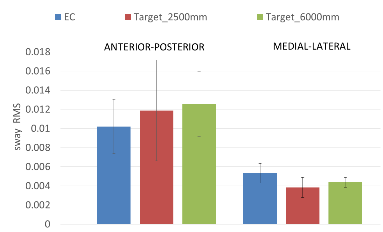

Figure 3: *Anterior-posterior body sway (left), medial-lateral body sway (right), average values (n=5)*

In the anterior-posterior direction, body sway is increased in both VR conditions compared to the eyes closed (EC) condition: By +16.5% and +23.2% with a fixation distance of 2500 mm and 6000 mm respectively. This decrease in stability for the virtual environment is based on the fact that the anterior-posterior movement does not evoke any perceivable change in the virtual environment, which consequently cannot provide any visual cues to increase stability. A different behavior is in the medial-lateral direction, where body sway is reduced in the VR conditions: -28.0% with a fixation distance of 2500 mm and -17.8% with 6000 mm. This is a relatively low decrease in medial-lateral body sway compared to a reduction of more than 300% in real world environments [Paulus et al. 1984]. The main help for an increased stability was reported to be the combination of the fixation point and the horizon that gave immediate feedback about instability. An explanation for lower stability in VR than in real world conditions is the significantly lower field of view, meaning less visual information, when wearing an HMD as discussed in [Kelly et al. 2008].

In Fig. 4, an exemplary track record of a measurement is shown. It is visible that the anterior-posterior sway is larger by a factor of 2, compared to the medial-lateral one. The accuracy of the HTC Vive is sufficient to measure postural stability.

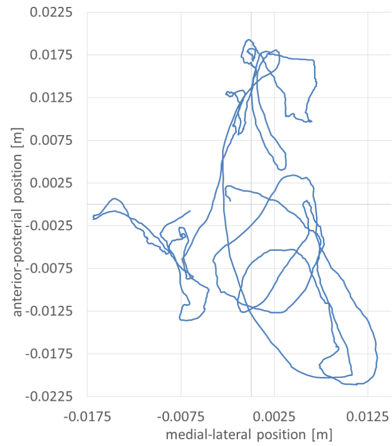

Figure 4: *Exemplary motion track visualization*

4 Summary and Future Work

We introduced a system to measure postural stability within a virtual environment. Due to the precise head tracking, the measurements showed that the system is superior to other VR systems and also could be used for rehabilitation at home.

Future work will focus on a more thorough user study, taking into account different levels of VR complexity. So far, only one target was shown. By adding another target behind the first one in varying distances, the possibility of perceiving motion parallax for medial-lateral sway is expected to further increase postural stability. Moreover, we want to integrate dynamic objects. By this, it is envisioned to also change the level of difficulty to adapt to a patient's therapeutic progress.

References

CHIAROVANO, E., DE WAELE, C., MACDOUGALL, H. G., ROGERS, S. J., BURGESS, A. M., AND CURTHOYS, I. S. 2015. Maintaining balance when looking at a virtual reality three-dimensional display of a field of moving dots or at a virtual reality scene. *Frontiers in neurology 6*.

EPURE, P., GHEORGHE, C., NISSEN, T., TOADER, L.-O., NICOLAE, A., NIELSEN, S., CHRISTENSEN, D., BROOKS, A., AND PETERSSON, E. 2014. Effect of the oculus rift head mounted display on postural stability. Reading University Press, 119–127.

HORLINGS, C. G., CARPENTER, M. G., KÜNG, U. M., HONEGGER, F., WIEDERHOLD, B., AND ALLUM, J. H. 2009. Influence of virtual reality on postural stability during movements of quiet stance. *Neuroscience letters 451*, 3, 227–231.

KELLY, J. W., RIECKE, B., LOOMIS, J. M., AND BEALL, A. C. 2008. Visual control of posture in real and virtual environments. *Perception & psychophysics 70*, 1, 158–165.

KESHER, E., KENYON, R., AND DHAHER, Y. 2004. Postural research and rehabilitation in an immersive virtual environment. IEEE, 4862–4865.

NISHIIKE, S., OKAZAKI, S., WATANABE, H., AKIZUKI, H., IMAI, T., UNO, A., KITAHARA, T., HORII, A., TAKEDA, N., AND INOHARA, H. 2013. The effect of visual-vestibulosomatosensory conflict induced by virtual reality on postural stability in humans. *Journal of Medical Investigation 60*, 3.4, 236–239.

PAULUS, W. M., STRAUBE, A., AND BRANDT, T. 1984. Visual stabilization of posture - physiological stimulus characteristics and clinical aspects. *Brain 107*, 1143–1163.

SCHULTE-PELKUM, J., AND NUSSECK, H.-G. 2007. Visual information and compensatory head rotations during postural stabilization. *Ratio 1*, 5.

WIEDERHOLD, B. K., AND WIEDERHOLD, M. D. 2005. *Virtual reality therapy for anxiety disorders: Advances in evaluation and treatment*. American Psychological Association.