Stabilization of oneself in Virtual Reality: Interaction of visual and vestibular cues

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• Motivation

Although the different sensory organs have quite different characteristics, it seems that we have no problems in their combined evaluation. To study this evaluation we chose the task of self stabilization, which is a well known task used for standing, walking, or slow bicycle riding. To perform this task would most probably require more than one sensory system. We want to answer these following questions:

- How do we evaluate the information that we get from the different sensory organs?
- Can we integrate these different types of information to improve our perception?
- Is it possible to transfer a learned skill from one modality to another?

• Equipment

We used a motion platform for the vestibular stimulus, a HMD for visual stimulus and a joystick as input device.

For the roll and yaw axis the visual stimulus was equivalent to the vestibular stimulus.

There were pre- and post-tests and six training sessions in between. During the training, one half of the subjects were trained only visually, the other only vestibularly.

• Experimental Design

The simulation was based on an inverse pendulum.

The motion platform and the HMD simulated the physical model of an inverse pendulum. Using the joystick, the subject could exert a force (acceleration) on the pendulum and thereby control the state of the model (see Fig. 4).

In our experiments, the subjects had to balance themselves on the pendulum against changes in roll, yaw, or both axes simultaneously. They had either vestibular information, visual information, or both. The visual stimulus was a random-dot cloud with limited life-time dots and an artificial horizon in order to match the character of the vestibular stimulus (absolute positional information for roll, but only information about changing of position for yaw).

Subject performed a pre-test, six training sessions, and a post-test. In the pre- and post-test sections, the subjects had to perform a stabilization task for all nine possible conditions. For the training section, the eight subjects were divided into two groups receiving only visual or only vestibular input (VISGroup and VESTGroup, respectively).

In the pre-test of the yaw-stabilization task, subjects performance was much better with visual than with vestibular stimulus (pre-test: vestibular 6.89°, visual 3.83°, t(7)=12.3, p<0.0001; post-test: vestibular 5.85°, visual 2.27°, t(7)=8.9, p<0.0001) (Fig. 7, right plot).

Finally, the VESTGroup showed a significant improvement (the ratio of performance in the post- to pre-test, t(7)=4.6, p<0.02) (see Fig. 8). This suggests that subjects are able to transfer their learned skill from one input modality to another (see Fig. 8).

Subjects can determine position from rotational acceleration.

The visual modality is more intuitive than the vestibular.

No combined evaluation of different modalities.

• Results

During the training section, the performance (the mean of the absolute positional error) of all subjects showed a large overall improvement. They improved their performance from pre- to post-test for the roll task and also for the yaw task (roll-task: pre-test 3.72°, post-test 2.16°, t(7)=4.9, p<0.002; yaw-task: pre-test 4.97°, post-test 3.67°, t(7)=5.3, p<0.002) (see Fig. 6).

In the pre- and post-test of the yaw stabilization task, subjects performance was much better with visual than with vestibular stimulus (pre-test: vestibular 6.89°, visual 3.83°, t(7)=12.3, p<0.0001; post-test: vestibular 5.85°, visual 2.27°, t(7)=8.9, p<0.0001) (Fig. 7, right plot).

Finally, the VESTGroup showed a significant improvement (the ratio of performance in the pre- and post-test in the visual roll task (on average 40% increase of performance from pre- to post-test, t(7)=2.9, p<0.023) (see Fig. 7, left plot).

The VISGroup showed also a large but non-significant improvement in the vestibular roll task (on average 32%). This suggests that subjects are able to transfer their learned skill from one input modality to another (see Fig. 8).

Subjects can determine position from rotational acceleration.

The visual modality is more intuitive than the vestibular.

No combined evaluation of different modalities.

• Conclusions

Subjects were able to do the yaw stabilization task in both modalities. This suggests that subjects can determine their position in space from the rotational acceleration.

In the pre-test for the roll task, subject perform much worse with the vestibular stimulus than with the visual. This suggests that the evaluation of the data from the vestibular modality is much harder than the data from the visual system for humans.

Figure 7 shows no increase in performance when both signals were available at the same time. So we can not confirm any model for sensor fusion, which does a combined evaluation from vestibular and visual stimuli.

For the roll task the visually trained group showed a significant increase of performance with vestibular stimulus. This suggest that the subject used the visually learned skill in the vestibular task, too.

References:


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