Novel Stereo Vision Test for Far Distances Measuring Perception Time as a Function of Disparity in a Virtual Environment

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Background and Purpose

Stereo vision is an important component of human vision for depth estimation. In most sports a more precise and faster depth estimation results in higher athletic performance.

The purpose of our work is to develop a system **to automatically evaluate the performance of human stereo vision**.

Basics

Depth can be simulated by displaying the projection of an object separately for each eye

Disparity denotes the offset between the two projections of the object (Figure 1a)

→ Depth impression in human stereo vision can be controlled by disparity

→ Disparity is given as an angle between the eyes and the object (Figure 1b).

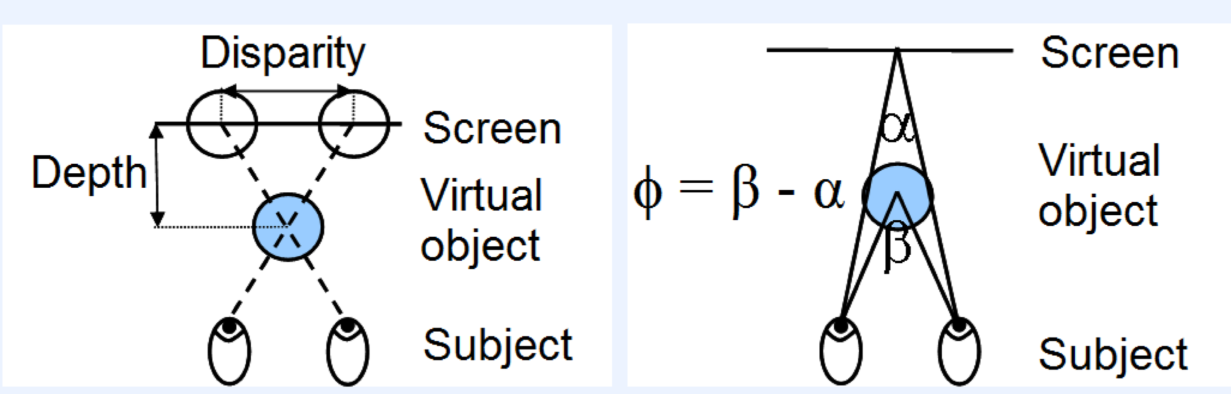

Figure 1: Principle for virtually simulating depth by generating an image for each eye separately (a). The horizontal offset is called disparity. Disparity is represented as angle ϕ in seconds of arc (b).

Key Ideas

Implementation of two major issues for human stereo vision performance

1. **Stereo acuity:** At which disparity is a correct depth estimation still possible?
   → *Correct decision rate*
2. **Speed:** How long does it take to resolve a certain disparity into a correct depth estimation?
   → *Average perception time*

→ **Perception time as a function of disparity**

Methods: Displays

The proposed stereo vision test was successfully tested on the following modalities (Figure 2):

- Dual projection with resolution of 1920×1080 and linear polarization
- Passive 3D TV with resolution of 1920×1080 and circular polarization

The graphical output of the proposed test is compatible with HDMI interfaces provided by commercially available 3D TVs.

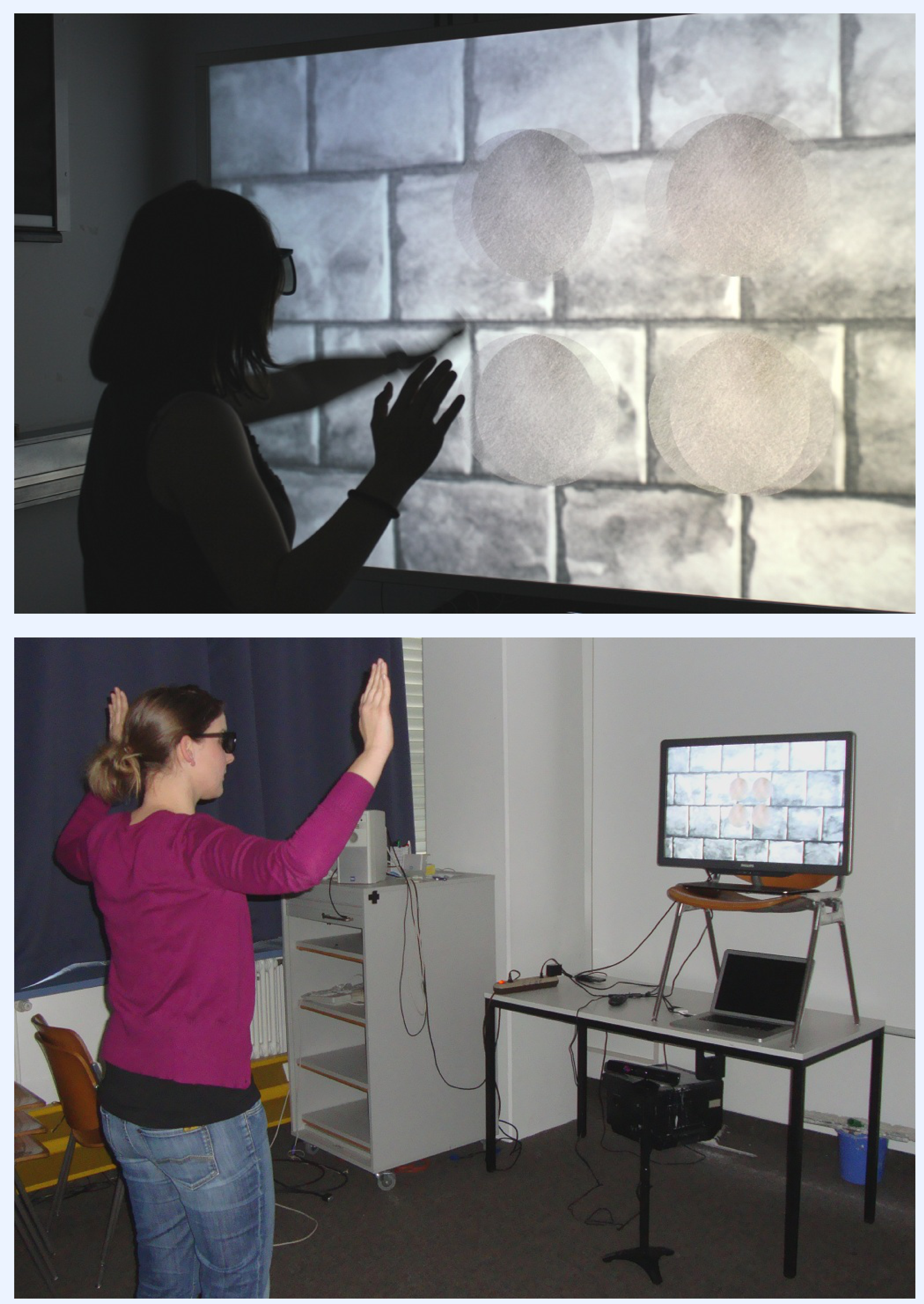

Figure 2: Subjects performing the proposed stereo vision test at lower distances on a polarized projection screen (top) and on a polarized TV (bottom). The images are generated on a common computer connected via HDMI to the display device.

Methods: Basic Test Procedure

The system provides a fully configurable and interactive stereo vision performance test.

- Four disks with same size
- One disk with larger disparity as front disk
- Random front disk in each iteration
- Depth sensor (Kinect^{TM}) for gesture control (Figure 3)
- Identification of front disk by pointing on it
  → Simple interaction for far distances
- Configurable disk size
- Configurable amount and extent of disparities

Measured values

1. **Correct decision rate** for front disk identification.
   It estimates the *stereo acuity*.
2. **Decision time** until subject points onto one disk.
   It estimates the *average perception time*.

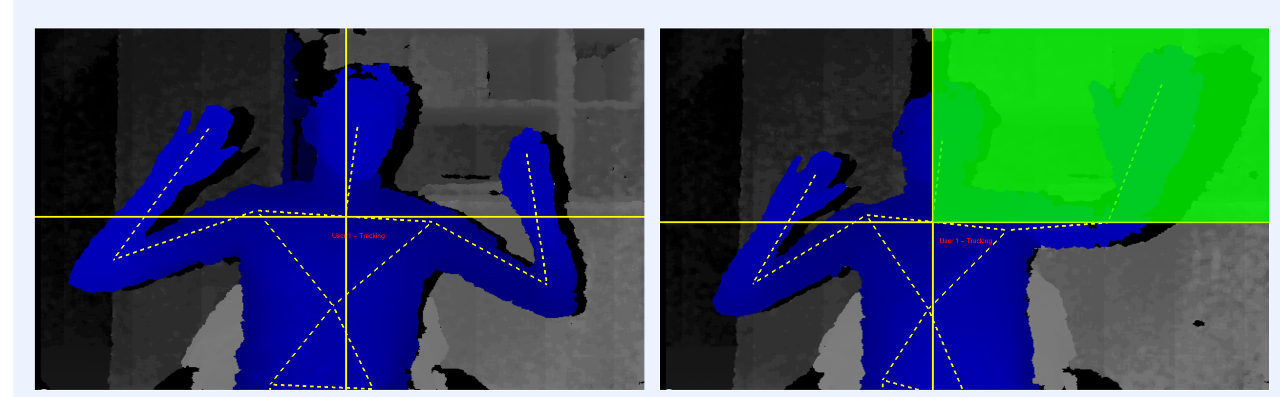

Figure 3: Example for the gesture control from the depth sensor's perspective. Solid lines represent sectors for selecting the corresponding disk. Hands near to shoulders means **no selection (a)**. Hands pointing in one sector means **selection of the sector's corresponding disk (b)**.

Methods: Study

The stereo vision test was used to evaluate the decision times as a function of decreasing disparity differences in seconds of arc (").

- Disparity differences: 300", 225", 150", 75", 15"
- 5 iterations for each disparity difference
- 10 healthy subjects (17-36 years) at a distance of 6m

We measured the average time for correct decisions for each disparity difference. A disparity difference was classified as detectable for at least 80% correct decisions (significance level of 5%).

Results

- **The decision times decrease with increasing disparity differences (Figure 4) and saturate in the range of 75"-300".**
- **The highest decision times are measured at the lowest disparity difference of 15".**
- At 75"-300": The decision times show a variation from 1234 ms to 2951 ms.
- At 15": The decision times show a variation from 2358 ms to 3877 ms.
- 2 subjects could not detect all disparity differences (not shown in results).

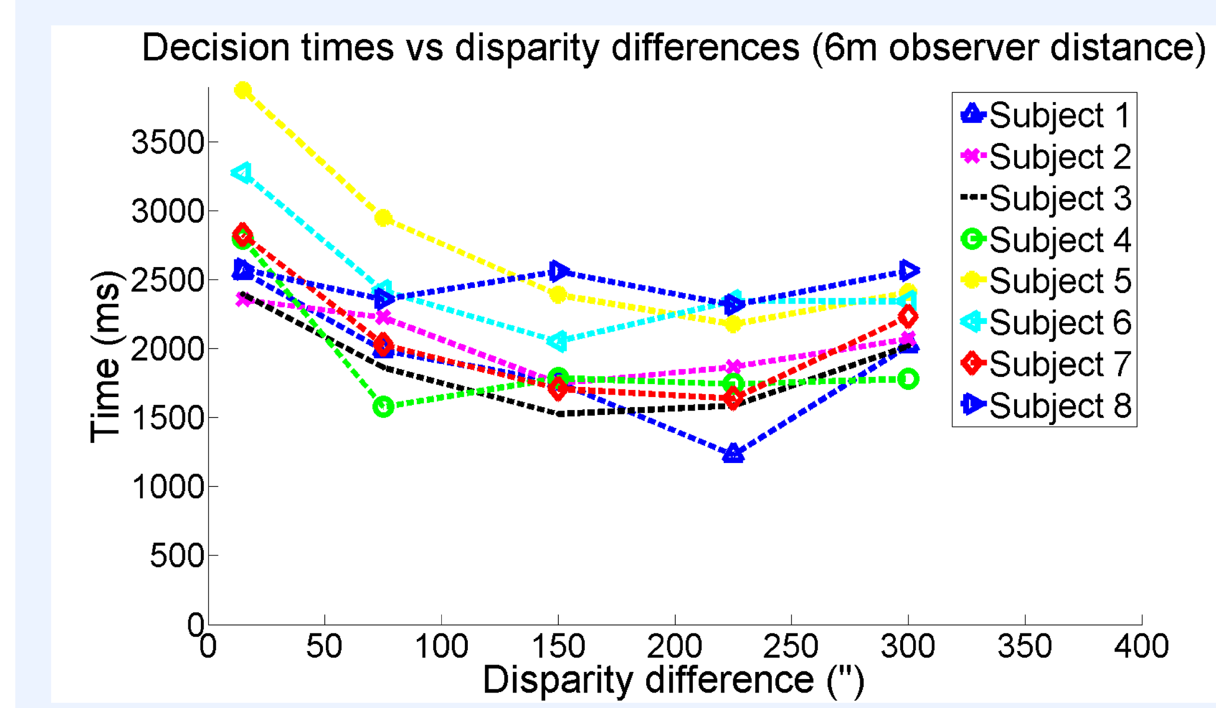

Figure 4: Average correct decision times for 8 subjects as a function of disparity differences. The highest decision times are measured at the lowest disparity.

Conclusion

We developed a **comprehensive stereo vision test** embedded in a **virtual environment**. It is able to reliably measure the performance of human stereo vision. An intuitive gesture control enables a simple interaction for far distances.

Support

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Commercial Relationship

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