Psychophysical Exploration of Stereoscopic Pseudo-Transparency

Mai Otsuki[1] Paul Milgram[2]

[1]Ritsumeikan University, Japan

[2]Dept. Mechanical & Industrial Engineering, University of Toronto, Canada

ABSTRACT

We report an experiment related to perceiving (virtual) objects in the vicinity of (real) surfaces when using stereoscopic augmented reality displays. In particular, our goal was to explore the effect of various visual surface features on both perception of object location and perception of surface transparency. Surface features were manipulated using random dot patterns on a simulated real object surface, by manipulating dot size, dot density, and whether or not objects placed behind the surface were partially occluded by the surface.

Keywords: Human factors, stereoscopic augmented reality, pseudo-transparency, transparency perception

Index Terms: [Computing methodologies]: Computer graphics - Graphics systems and interfaces - Mixed / augmented reality, Perception. Psychophysics.

1 INTRO: STEREOSCOPIC PSEUDO-TRANSPARENCY

One of the challenges facing the practical application of augmented reality (AR) in domains such as endoscopic surgery [1, 2, 4] is how to cause a virtual (computer generated) image to appear behind a real object surface. When using video based stereoscopic displays (that is, either see-through or monitor based video), a conflict occurs between the binocular disparity depth cue, which tells the observer that the virtual object is behind of the real object surface, and the occlusion depth cue, which tells that the virtual object must be front the real surface. The net effect of overcoming this conflict and successfully creating the desired impression occurs when the intervening (real object) surface appears to be semi-transparent, with the effect often referred to as pseudo-transparency [1, 6].

We report a experiment related to perceiving (virtual) objects in the vicinity of (real) surfaces when using stereoscopic augmented reality displays.

2 EXPERIMENT

2.1 Image Generation

All stimuli were generated on a desktop computer (Windows 7 Professional OS, Intel Core i5 2310 2.8 GHz CPU, 8G RAM, with NVIDIA Quadro 600), coded using Visual C++ 2010 and were presented on a 23-inch LCD screen (ASUS VG236HE, 1920 x 1080 resolution, 120-Hz refresh rate) with a black background. Stereo images were observed using a nVidia 3D vision system, with 3D Vision 2 glasses.

Fig. 1 shows experimental setup and the sample stimulus shown to participants. Although the paragraphs above refer to real surfaces and virtual objects, the "real surface" that we used in our experiment was a simulated real surface for the sake of expediency. – the 'coloured surface' in the figure. For our virtual object, we used a blue circle, whose position in the depth direction could be produced at various distances in front of (closer to the participant) or behind the coloured surface. For the textured surface, we used a pattern of random dots. We define the entire circular pattern of dots and surface elements as 'masking window' for participants' comfortable. We varied the random dot patterns in terms of the size and density of the dots. Fig. 2 shows all stimuli used in the experiment. *Dot size* is the fraction into which each dimension is divided (e.g. 1/20 means that a 20x20 grid was used to generate the random dot pattern). *Density* is the percentage of the entire masking window that consisted of dots. These are independent of each other.

Figure 1. Experimental setup and typical stimulus

All images were rendered stereoscopically, with the coloured surface held at a constant distance corresponding to zero disparity. The virtual circle was produced to be either in front of the surface, or behind the surface. For generality, all of the distances used in this report are in program units, where one unit = 116.5 mm..

We used two different rendering methods in the case that the circle is behind of the surface. *No Occlusion* (nOC, the left two rows of Fig. 2), we ignored any depth relationship between the circle and the surface, such that the circle pixels would occlude all elements of the coloured surface, regardless of whether it was drawn in front of or behind the surface. This corresponds to the condition we hypothesised should be conducive to perception of stereo-transparency [1, 6]. (It also corresponds to the case in which one does not have a model of the real surface, which would be necessary in order to implement occlusion in practice.) Opposite to this, *Occlusion* (OC, the right two rows of Fig. 2), we treated the black dots and the remaining portions of the coloured surface differently. This was hypothesised to correspond to the case of pseudo-transparency, in the sense of simulating the case of light passing through gaps in non-transparent ('lacy') objects [6].

2.2 Participants

We recruited 15 University of Toronto students over the age of 21 (18 male, 3 female) who have normal or corrected visual acuity, as well as were confirmed no problems with stereoscopic vision by the nVidia 3D stereo vision test was administered.

2.3 Purpose and Procedure

This experiment was consisted two parts. Part 1 was to explore whether there is a perceptual bias in either direction when placing a virtual cursor near a surface, as well as to estimate what degree of sensitivity is to be expected, using the method of constant stimuli [3]. Following a brief training session to familiarise

---

[1] otsuki@rm.is.ritsumei.ac.jp

[2] milgram@mie.utoronto.ca

IEEE International Symposium on Mixed and Augmented Reality 2013
Science and Technology Proceedings
1 - 4 October 2013, Adelaide, SA, Australia
978-1-4799-2868-2/13/$31.00 ©2013 IEEE

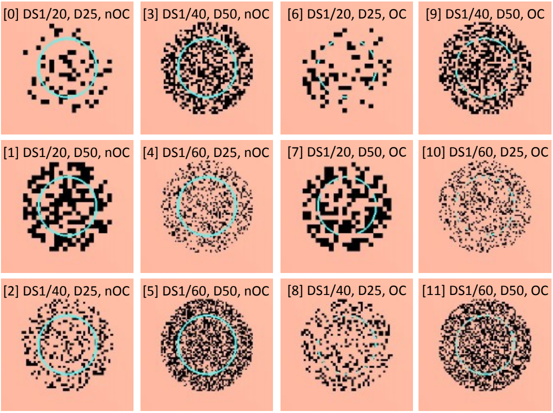


Figure 2. Stimuli for experiment. DS=Dot size, D=Density, OC=With Occlusion; nOC = No Occlusion

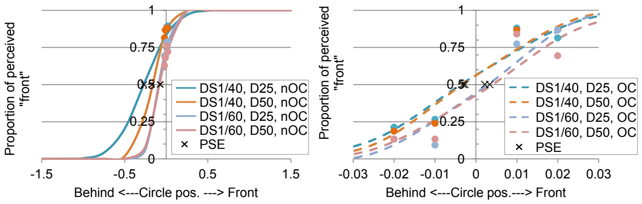
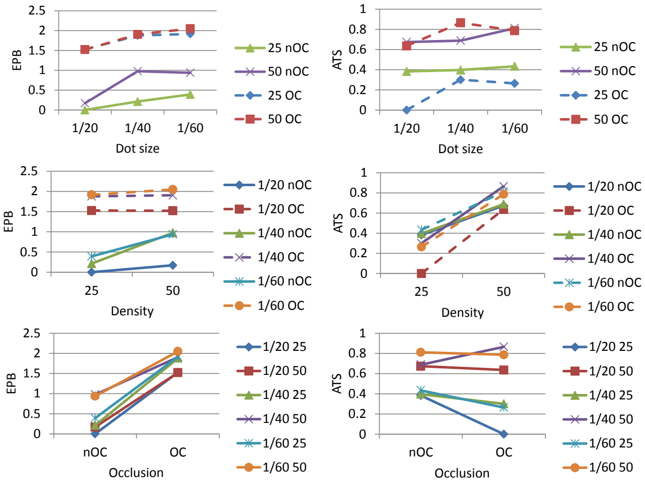


Figure 3. Psychometric functions for all stimuli. (NB: *Note different scales: left graph has 50 times width of bottom graph.)*



(a) Ease of perceive behind; EPB

(b) Apparent transparency scale; ATS

Figure 4. Result of experiment 2

themselves with the interface and procedure, participants were shown a series of stimuli (#2-5 and 8-11 in Fig.2), responded whether, according to their judgement, the circle was in front of or behind the masking window. The virtual circle was presented at four distances relative to the masking window {+/– 0.01, 0.02}, with 5 trials for each combination of conditions (i.e. 160 trials for each participant.). These particular values were selected following extensive pilot testing. The order of stimuli was randomized

In Part 2, it was both to explore the extent to which the various simulated surface textures were amenable to being perceived as transparent, and to create a quantitative scale for assigning perceived transparency values to various surface feature by Thurstone's paired comparison scaling method [5]. The virtual blue circle was always at the same distance {-0.1} behind the masking window. The participants were required to answer the two questions. (1) "In which image is it easier to perceive that the circle is behind the masking window?" and (2) "In which image does the masking window appear to be more transparent?" All stimuli shown in Fig. 3, 66 (${}_{12}C_2$) comparisons necessitated.

2.4 Results and discussion

In Part 1, (1) All resultant graphs (Fig. 3) conform well to the cumulative normal probability function models fit to the data. Note, however, that the horizontal axis in the left graph is 50 times as wide as that of the bottom graph. In other words, the sensitivity for perceiving the circle relative to the coloured surface is markedly less for the *nOC* case (left graph) than it is for the *OC* case (right graph). The just noticeable difference (JND) values for all of the *nOC* cases are much larger than those for the *OC* cases.

(2) There is clearly a large perceptual bias for the *nOC* results (Fig. 3., left) This is illustrated by the X symbols, (PSE; Point of Subjective Equality). In the *nOC* conditions (Fig. 3 left), on the other hand, the PSEs are much farther behind the centre of the graph, meaning that for surface textures comparable to those tested here, one should expect to encounter a bias towards perceiving the cursor as being behind the surface, under the belief that it is on the surface.

The results for the four surface texture conditions tested are less dramatic in comparison with the *OC* / *nOC* conditions.

In Part 2, Fig. 4 shows the scale value results (the vertical axis) for (a) Ease of Perceiving Behind (EPB), and (b) Apparent Transparency Scale (ATS). In each graph, the rating scale values, where larger values signify more agreement among participants, in units of standard normal deviates, about corresponding parameters being rated.

The bottom EPB graphs indicate clearly that it was easier to perceive that the circle was behind the surface in the *OC* condition than in the *nOC* condition. For the bottom ATS graphs, on the other hand, any influence of the occlusion condition. In contrast, the most striking effect evident from the ATS scale values is the influence of *Density*. These results suggest that perceiving the circle behind the surface is not the same process as perceiving the masking window as transparent.

3 CONCLUSIONS AND FUTURE WORK

We found the occlusion cue for perceiving object location relative to a surface, as well as the importance of *Density* for perceiving surface transparency. The results of this experiment have implications for the ongoing challenge of facilitating the perception of surface transparency in augmented reality.

For the future work, our initial investigations of monitor based stereo augmented reality surface texture effects could be carried out using a simulated real object surface, for the sake of expediency. It will definitely be necessary to confirm our findings using actual real object surfaces with real stereo video sensors.

REFERENCES

[1] R.A. Akerstrom *et al*. The perception of stereoscopic transparency. *Perception & Psychophysics*, 44 (5), pp. 421-432, 1988.

[2] C. Bichlmeier *et al*. Contextual anatomic mimesis hybrid in-situ visualization method for improving multi-sensory depth perception in medical augmented reality. *In Proc. ISMAR '07*, pp. 1-10, 2007.

[3] G. Gescheider, Psychophysics: The Fundamentals. 3rd Edition. Erlbaum, 1997.

[4] S. Nicolau *et al*. Augmented reality in laparoscopic surgical oncology. *Surgical Oncology*, 20 (3), pp. 189-201, 2011.

[5] L.L. Thurstone. The method of paired comparisons for social values. *J. Abnormal & Social Psychology,* 21, pp. 384 - 400, 1927.

[6] I. Tsirlin *et al*. Perceptual artifacts in random-dot stereograms. *Perception,* 39, pp. 349-355, 2010.