Biomedical Engineering Society (BMES) Anuual Meeting, Seattle WA, Sept. 25-28, 2013

Studying Depth Perception to Aid Microsurgery: Developing a Novel Visual Stimulus that Lacks Pictorial Depth Cues but Contains Sufficient Information to Allow Stereopsis

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Introduction: Microsurgery is very challenging, since surgeons have to perform delicate operations on small objects with high accuracy and precision. While instruments like stereoscopic microscopes allow the surgeon to see the details better, they also cause some undesired effects in the surgeon's perception of depth. The oculomotor cues from convergence of the eyes are essentially eliminated by the optics of the microscope, and the disparity values (differences between the images to the two eyes) vary only slightly, even along a severely slanted image. In addition, pictorial cues like texture gradients are altered under magnification. Previous work has not assessed the effect of magnification on stereo depth cues independently of other cues, particularly the texture gradient. The goal of this work was to develop a type of stimulus that eliminates texture gradients while retaining sufficient shape features to allow stereopsis to occur. Measurement of the accuracy of slant perception of such a stimulus under normal viewing is a first step toward understanding the effects of magnification. Such stimulus patterns are to be used in future work, in which slanted features from imaging technologies are used to augment microscopic views. Findings from these studies can be used to improve technologies aimed at aiding microsurgery.

Materials and Methods: The method of creating an image free of any texture gradients was to generate and plot a large number of overlapping translucent triangles at various sizes and orientations. Triangles were chosen as the building block of the images, because they have well specified shapes and edges, and they are devoid of parallel lines which would converge under slant, providing a clear perspective cue. Each triangle was the largest that could contain an inscribed circle of a radius specified for that triangle, subject to constraints on angles to prevent near parallel edges. The radii were drawn from a continuous distribution of sizes, biased toward small values to maintain constancy of the observable image statistics under zoom. An experiment was designed to verify that the resulting image eliminated pictorial depth cues while maintaining stereo cues to slant. Subjects viewed a series of images, rendered either in stereo (disparity in cues to the two eyes corresponding to a particular depth) or non-stereo (identical images to both eyes) conditions and indicated their direction of slant. Possible slants were 0° (frontal), or ±15° or 30° in pitch or yaw. Each stimulus was either drawn from the experimental set or was a tiled surface, which was a control providing textural gradient cues. We hypothesized that people would be unable to discern the direction of tilt when seeing the experimental images in the non-stereo viewing condition; however, when viewing in stereo, they would accurately report slant. The control images should be accurately perceived in both viewing conditions.

Results and Discussion: The results of a pilot study with 12 subjects confirmed our predictions that the experimental triangle-based stimuli could be perceived in depth under stereo conditions but not under non-stereo. This indicates that our algorithm for stimulus generation effectively eliminated the texture gradient cues, but still provide sufficient information to enable stereo depth perception. Under non-stereo viewing, the average accuracy of slant report was 88% for control images versus 25% for experimental images. In the stereo condition, average accuracies were 95% for control and 91% for experimental, which were statistically equivalent. Essentially, performance was near the maximum possible for all conditions except the non-stereo experimental stimuli, which resulted in performance only slightly above chance.

Conclusions: The results of this experiment indicate that we have created a stimulus that affords little or no pictorial depth cues but still allows stereopsis, thereby enabling future experiments to isolate individual depth cues when testing true slant perception. Future work will include testing subjects' ability to view slant using these images under a microscope, and then testing different methods of improving this ability.

Acknowledgements: This research was made possible by NIH grant R01EY021641.