Stereo perception of reconstructions of digital holograms of real-world objects

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Abstract. In digital holography a 3D scene is captured optically and often the perspectives are reconstructed numerically. In this study we digitally process the holograms to allow them to be displayed on autostereoscopic displays. This study is conducted by subjective visual perception experiments comparing single reconstructed images from left and right perspective to the resulting stereo image.

1. Introduction

In contrast to conventional holography, in digital holography [1] we often capture optically a 3D scene and reconstruct the desired perspectives numerically in a computer. The reconstructions are routinely displayed in the form of a 2D image slice through the reconstruction volume, an extended focus image, or a depth map from a single perspective. These are fundamentally 2D (or at most 2.5D) representations and for some scenes are not certain to give the human viewer a clear perception of the 3D features encoded in the hologram (occlusions are not overcome, for example). In addition digital numerical reconstructions are limited by speckle noise and limited depth of field.

Alternatively, an optical reconstruction would allow the human viewer to extract the 3D information themselves through stereopsis and motion parallax, but convincing full-field digital holographic displays for real-world 3D scenes have not been demonstrated due to current limitations of programmable display devices.

As an intermediate measure, we have digitally processed the holograms to display them on conventional autostereoscopic displays, which provide a readily understood and off-the-shelf available technology, and the human visual system itself extracts the 3D information of the scene encoded in the hologram. Previously we have reported results suggesting that when digital holographic reconstructions are displayed stereoscopically people perceive less speckle noise and increased depth of field [2,3]. In this paper we show more detailed results how displaying the reconstructions in stereo reduces the perception of noise, increases the detail visibility and general enhances perceived quality when compared to displaying the reconstructions as 2D images. Also we will show how noise perception changes as more hologram data (larger window) contributes to the reconstruction.

2. Method – subjects, apparatus, stimuli, procedure

The experiment was performed with thirteen subjects with normal or corrected-to-normal vision. Stimuli were presented on autostereoscopic display (Sharp LL-151-3D, 1024×768 pixels in total). The

viewing distance was approximately 60 cm. We presented subjects with reconstructions from five different holograms, using six different window sizes (apertures on the hologram data) and two perspectives (left and right) from each hologram. We asked subjects to evaluate reconstructions of individual left and right perspectives, and resulting stereo pairs. Subjects answered either yes or no to questions: "Does noise disturb?" and "Are details visible?" They also evaluated the quality of images on scale 1–5 (1= very poor, 5=very good quality).

3. Results and discussion

The results from the experiment are shown in Figs. 1(a) and 1(b) as percentage of "yes" responses, and in Fig. 1(c) as an average over the thirteen subjects and five holograms. Compared to single images, Figure 1(a) shows that there is less disturbing noise in stereo images, Fig. 1(b) shows that more details are visible in stereo, and Fig. 1(c) shows that stereo images are perceived as being of higher quality.

The limitation on these results is that they are not quantified by psychophysical methods. Perceptual performance can be effectively measured by psychophysical methods such as threshold estimation techniques. Psychophysical threshold estimation methods produce highly accurate and quantitative ratio scale level descriptions of human performance, for example, the minimum amount of disparity that can be discerned with a given probability or the minimum time required for the recognition of a 3D object. In order to further investigate enhanced quality and noise reduction phenomena described here and extended focus phenomena described previously [2,3] we need to measure both perceived quality and perceived "stereo effect" by psychophysical methods. We propose to quantify binocular depth fusion by doing a specific experiment with increased depth of field stimuli.
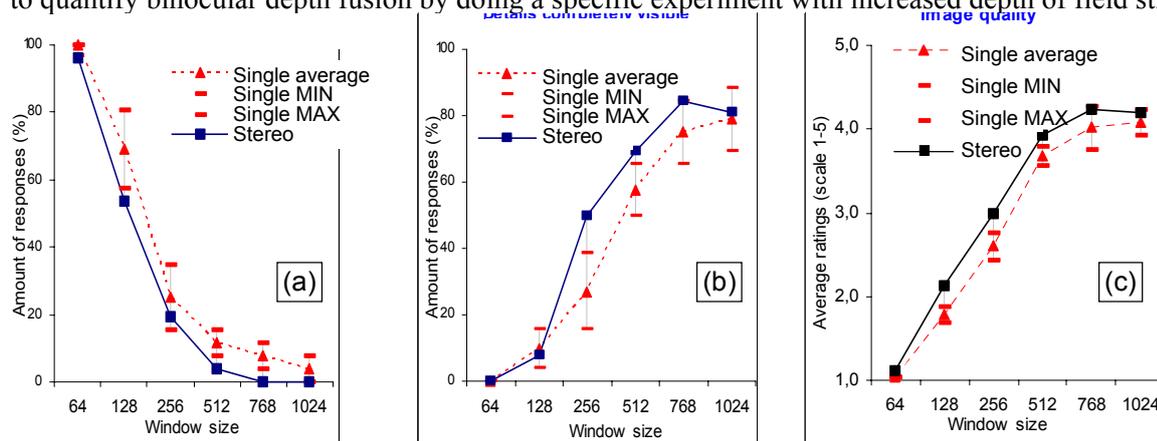

Figure 1. Comparisons between single images (left and right reconstructions) and corresponding stereo images for different window sizes. MIN corresponds to single left or right image that got the least "yes" responses (MAX is most responses). On vertical axis (a) percentage of "yes" responses to: "Does noise disturb substantially?" (b) percentage of "yes" responses to: "Are details completely visible?", and (c) Evaluated quality using scale 1-5 (1= very poor, 5=very good quality).

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References

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