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A new experimental technique for generating anaglyph stereo images for sculpture arts

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Abstract In this paper, a new experimental technique for generating anaglyph stereo images for three-dimensional visualization of sculpture arts is proposed. The images are taken at fixed distance using the imaging system consisting of single CCD camera and turntable. This system allows generation of stereo images at variable distances from the target object. The feasibility study of this technique is demonstrated by showing some anaglyph stereo images of a sculpture art.

Keywords Three-dimensional visualization · Anaglyph · Stereo image · Sculpture · Scientific arts

1 Introduction

In recent years, three-dimensional visualization is becoming an important topic of interest in the field of visualization, and is often applied to the field of scientific arts, such as sculpture, rhythmical movement, fine arts and so on (Hertzberg and Sweetman 2005; Burge 2007; Brown 2007; Sakashita et al. 2007; Fujisawa et al. 2007, 2008). As the three-dimensional visualization reproduces the depth information of the target object, the application of this technique is becoming popular in the visualization of sculpture arts, which requires reality and artistic impression in the target objects.

Anaglyph is one of the well-known methods for viewing stereo images, and is also the most economical method for application to the observation of three-dimensional visualization. It reproduces the depth information of the target object, when it is observed through red and cyan filtered glasses. The red filter on the left eye allows only the red part of the anaglyph image through, while the cyan filter over the right eye allows only the blue and green parts of the image through. Thus, the depth information of the target object can be seen from the anaglyph stereo images by viewing two slightly different pictures placed on the anaglyph by different color filters. Therefore, the anaglyph stereo images are often generated by standard method using two parallel cameras placed side by side in a human interpupillary distance between eyes. They can be generated from the depth information of the target objects, too (Ideses and Yaroslavsky 2005; Matsuura and Fujisawa 2008a, b). The standard method allows the anaglyph stereo visualization of the target object at a fixed distance of the cameras position, so that there are great efforts for generating the anaglyph stereo images in whole three-dimensional space around the target object, which is often required in the production of stereo images for sculpture arts.

The purpose of this paper is to propose a new experimental technique for generating anaglyph stereo images applicable to whole three-dimensional space around the target objects, using an imaging system that consisted of single CCD camera and turntable.

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2 Experiment Method

When planar images are taken from various view angles around the target objects, anaglyph stereo images are generated from neighboring two images, which correspond to the human interpupillary distance of human eyes. Figure 1 shows an illustration of the experimental apparatus for generating such anaglyph stereo images. Illumination is provided uniformly from the top of the target object, while the observation is made by a monochrome CCD camera (648 × 494 pixels, 8-bit), which is placed on a vertical traversing device with small turntable for setting of the elevation angle. Note that the imaging and the motion of the turntable for target object are synchronized using a pulse controller equipped with a personal computer. In the present experiment, images around the target object are acquired at every 1° interval of horizontal angle during the rotation of the turntable. Therefore, 360 images in total are acquired in one cycle of the rotation. Image acquisition was carried out by the change of elevation angle of the camera 0°, ±4°, ±8° and ±12° measured from the horizontal plane. Thus, the total number of captured images is 2,520 in the present experiment. Note that the distance between the CCD camera and the target object is fixed to 1.3 m. Therefore, images are taken at every 23-mm interval around the target object.

Examples of captured images are displayed in Fig. 2, which corresponds to those of elevation angle 0° with horizontal angles of every 1° and 10° interval. These image data allows the generation of anaglyph stereo images at every camera position by selecting images at a certain distance, which corresponds to the human interpupillary distance of 63 ± 8 mm (Dodgson 2004). In the present study, two images are selected to have a distance of 68 mm, because it is closest to the average human interpupillary distance of 63 mm. It should be mentioned that the distance between the virtual camera and target object L_i can be obtained from the following equation:

$$2L_i \sin(\pi i)/N) = H. \quad (1)$$

This can be simplified to the following equation, assuming that i is much smaller than N.

$$2\pi i L_i/N \approx H \quad (2)$$

where H is the human interpupillary distance; i, the image number counting from the image in front of the target object (i = 1, 2, 3, …); N, the total number of images taken in one cycle of rotation. The distance between the virtual camera and target object L_i determined from the equation shows a discrete value, which can be obtained more precisely by acquiring more images and selecting a suitable image pair during a rotation of the turntable with the cost of computer memory.

The present experimental technique allows generation of stereo anaglyph images at short and long distances from the target objects as well as those of the fixed position of the camera. Figure 3 illustrates how images are chosen from captured images. The anaglyph images on the camera distance are generated from the original stereo-pair images ($A_{L,}$ A_R) using the standard method. The stereo-pair images ($B_{L,}$ B_R) at short distance L_S are generated from the stereo-pair images (B_L',B_R') at camera distance L_C with magnification

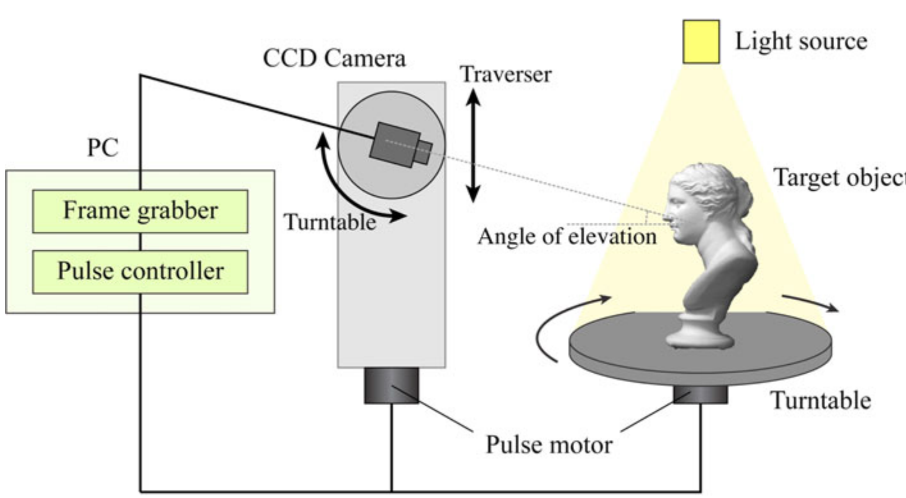

Fig. 1 Illustration of experimental apparatus

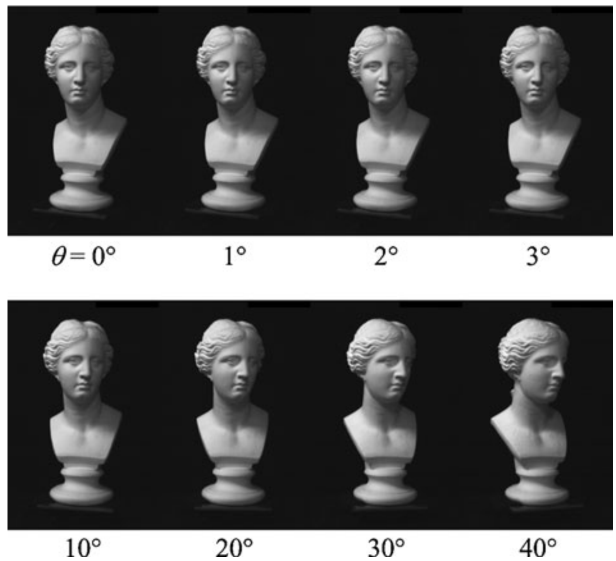

Fig. 2 Example of images taken from single camera

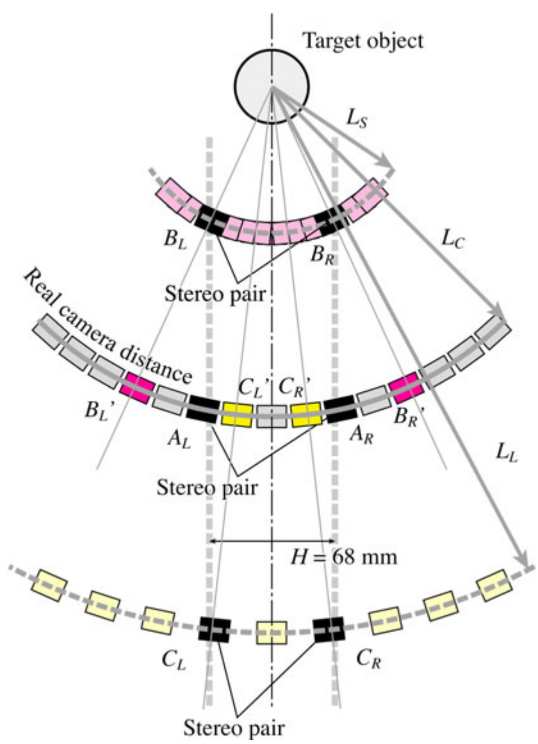

Fig. 3 Anaglyph stereo-pair images at short and long distances

operation. The magnification ratio is determined by L_C/L_S from the geometrical similarity. On the other hand, the stereo-pair images (C_L, C_R) at long distance L_L can be obtained from stereo-pair images (C_L', C_R') at the camera distance L_C with the selection of stereo-pair images of human interpupillary distance in combination with reduction operation. The reduction ratio is determined by L_C/L_L. It should be mentioned that the selection of stereo-pair images at long distance becomes coarse due to an increase in the distance between neighboring images and is vice versa for short distance. Note that the operation of magnification and reduction is carried out using commercial software for image processing. Such anaglyph stereo images for short and long distances cannot be generated from the standard method. Therefore, the present technique allows the anaglyph stereo visualization of target object applicable to variable distances in the whole horizontal plane with single camera. However, there is a limitation of magnification and reduction operation for generating the anaglyph stereo images. When the virtual camera position is much deviated from the real camera position, there will be an image distortion between the two observations. Therefore, the magnification and reduction operation cannot be applied to all cases of the virtual observation, such as the virtual camera very close to the target object. In order to solve this problem, the virtual camera should be placed in the region where the ratio of the object size to the virtual camera distance is not so deviated from that of the object size to the real camera distance.

3 Results and discussion

Examples of anaglyph stereo images generated in the present study are shown in Fig. 4. These anaglyph stereo images reproduce three-dimensional structure of sculpture arts by the observation through red filter on the left eye and cyan filter on the right eye. Figure 4a, b shows the comparison between the standard anaglyph stereo images taken by the two parallel cameras (Fig. 4a) and that taken by the single camera in combination with the turntable (Fig. 4b). Although there is small amount of difference in the angle of observation for two stereo images, the results indicate similar depth information. Therefore, the present technique reproduces the three-dimensional effect correctly, which is similar to the standard method.

Figure 5a, b shows examples of anaglyph stereo images generated at short and long distances from the target object, respectively. The target distance is 0.65 m for the short distance and 1.95 m for the long

Fig. 4 Comparison between anaglyph stereo images created by standard and present method. **a** Standard method (1.3 m), **b** present method (1.3 m)

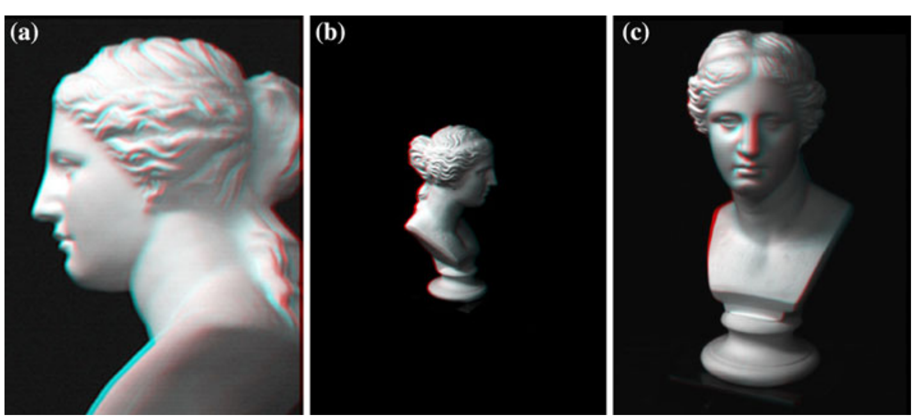

Fig. 5 Examples of anaglyph stereo images at variable distances from target object. **a** Short distance (0.65 m), **b** long distance (1.95 m), **c** different angle (1.3 m, 12°)

distance. Note that the human interpupillary distance is set to 68 mm. Figure 5c shows an example of anaglyph stereo image viewing from 12° from the horizontal plane. The generated anaglyphs reproduce the three-dimensional effect and the artistic impression as well. Therefore, the present technique can be applicable to the generation of anaglyph stereo images at variable distances from the target objects in the whole three-dimensional space.

It should be mentioned that anaglyph stereo images could be generated from the three-dimensional surface data of the target object, as described by Matsuura and Fujisawa (2008b). In order to accomplish this, the three-dimensional surface data has to be measured before generating anaglyph stereo images using experimental methods, such as scanning laser light, interferometry and calibrated stereo imaging. But, this requires more expensive experimental facility and data analysis than the present method. Therefore, the present method is straightforward for generating anaglyph stereo images with reasonable cost.

4 Conclusions

A new experimental technique for generating anaglyph stereo images is proposed in the present paper. The experimental system consisted of single CCD camera and turntable driven by a stepping motor. This experimental technique is straightforward for generating anaglyph stereo images with reasonable cost, and is successfully applied to the anaglyph stereo visualization of sculpture arts at variable distances from the target objects in whole three-dimensional space.

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