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A New Technique for Improving Camera Shooting

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Abstract

This paper presents a new technique for improving camera shooting using moving parallel method. With ordinary stereovision shooting techniques using many cameras arrayed in parallel, the convergence distance to sense the distance to the target being viewed does not match with the focal distance to obtain sharp retinal images. This causes visual burden that is unique to stereovision. The authors have been working on a mechanism to adjust the convergence of the stereo cameras and a technique to reduce the visual burden caused by attempting to match convergence and focal distance. Visual burden was successfully reduced using cross points but it was found that space perception was distorted in the peripheral vision. The authors have developed a new stereo image shooting method to correct distortion in space perception and reduce the visual burden as much as possible. The present paper reports on this new shooting method.

***Keywords**: Camera shooting, stereovision system, visual burden, remote operation*

1. Introduction

Humans desire three main qualities for visual media:

1- to be able to see distant views
2- to be able to fix the view in front of the observer
3- to be able to represent imagined scenery This desire is inherent to humans and has driven the development and spread of the media we see today. Consumers increasingly see stereovision, such as on mobile phones and game machines with 3D liquid crystal displays, as a result of the development of advanced technologies.

Stereovision is natural to humans and perspective and sense of distance are important sensual information essential in daily life. The present study aims at verifying and establishing the practical use of stereovision and the development of a remote stereovision system (RSVS).

1.1. Factors of Stereovision

Important factors of stereovision are classified into three categories in the present study: 1) Internal stimulation, 2) Single images, and 3) Binocular vision. Of these, the effect of depth perception by disparity is relatively important. Reproduction of internal stimulation (1) is difficult. Remote stereovision will be realised by presenting images based on single images (2) and binocular vision (3). Particularly important is the scheme of modelling and transmitting binocular vision to the observer, or how to view different images with the right and left eyes independently.

1.2. Reproduction of Stereovision

Various stereovision systems are available today. By type, they include viewer, glass and naked eye systems. Time-sharing shutters are adopted in the RSVS. The right and left images are alternately

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displayed at high speed and the LCD shutters of the goggles switch synchronously. The right and left eyes view only the right and left images, respectively, to achieve independent right and left vision. The image quality is not deteriorated, and this is one of the features of the system developed by the authors.

2. Outline of RSVS

Figure 1 shows the overall functional structure of the system. Each component will be described, followed by the plan for realisation.

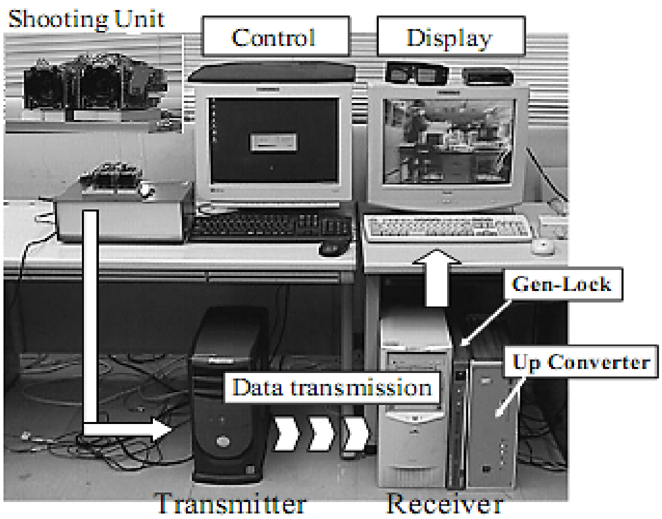

Fig. 1. Remote stereovision system

Shooting Unit: To imitate the human vision mechanism for acquiring factors of stereovision by disparity, two cameras are arrayed, each corresponding to the right and left eyes. Standard camera functions such as zoom and auto-focus are incorporated to adjust the image quality.

Transmitter: Stereo images are transmitted for viewing stereovision remotely. Established networking technologies and the Internet infrastructure are used to send the stereo images. MPEG-2 image compression was selected because wide ranges of compatible commercial products are available on the market.

Display: For an observer to view stereovision remotely, the received stereo images must be displayed to present independent right and left views. To develop the display, stereo image display technology and hardware were selected and developed based on the development concept.

The RSVS Versions 1 and 2 have been prototyped in the present study. RSVS Version 2, which is currently used, is designed to achieve remote stereovision with high image quality. The right and left images are compressed to MPEG-2 and remotely transmitted after synchronising. The received MPEG images are decoded to video signals and converted to double- speed (60 to 120 Hz) images by an up-scan converter for alternate display. Images for each side of the stereovision are alternately displayed on a 720 x 480 pixel screen for very sharp images and the resultant clear stereovision. The transmission rate for the binocular images is about 13 Mbps. The transmission delay is about 1 sec, which poses a problem for real- time observation. The authors will improve the RSVS for real-time viewing while maintaining high image quality.

3. Visual Burden

Visual burden in stereovision systems comes from the sense of fatigue caused by wearing gadgets such as glasses and the mismatch with the visual system. While recent display units feature ever-higher resolution and hardware is lighter due to advanced technology, mismatch with the visual system has not been discussed much by researchers. Stereo image shooting cameras are generally arrayed and fixed parallel to each other. This means that the information on disparity in the shooting space is fixed. This is similar to looking at an object within the visual field while watching a certain distant point in ordinary vision, and it is very unnatural. The authors believe that this unnatural condition causes a burden to the brain that is manifested as a visual burden, and offer adequate binocular images to reduce visual burden in the present paper.

3.1. Cross Method and Parallel Method

Two methods are used to shoot stereo images: the cross method and the parallel method. The features of these methods are described below.

Parallel Method: The right and left cameras shoot images with their optical axes kept parallel to each other. The obtained images are free from geometrical distortion. But the stereovision viewer must diverge their eyes. The parallel method is effective for shooting distant views.

Cross Method: The optical axes of the right and left cameras are crossed. This is the most popular stereo image shooting method. The cross point of the optical axes of the cameras is reproduced on the stereo display plane. Stereo effects are adjustable by selecting the object on which the cross point is set before shooting.

3.2. Visual Burden due to Different Convergence Distance and Focal Distance

When stereo images taken using the parallel and cross methods are shown on a display, the difference of convergence and accommodation becomes apparent. In natural vision, convergence and accommodation rest on a single object. Assume the cross point is set on a different point than the object (in front of or in back of the object), then the convergence of the viewer of the stereo images moves to the stereo image while accommodation stays in the same place on the display. Convergence moves stereoscopically to the back and front of the display while accommodation basically moves plenary on the display. This poses a problem in that convergence of the visual system and accommodation provides different information about distance to the viewer of the stereo images, leading to a mismatch of stereo effects and visual system (figure 2).

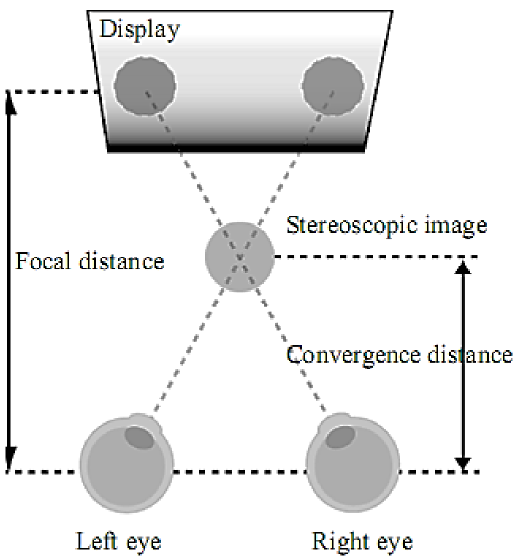

Fig. 2. Disagreement of distance information

The authors believe that the different information about distance given by convergence and accommodation or an unnatural visual environment makes the viewer uneasy and causes visual burden at least partly. To alleviate the visual burden, convergence is adjusted by changing the optical axes of RSVS cameras to provide a visual environment in which the distance of convergence and accommodation agree with each other relative to the object being viewed.

3.3. Shooting with Convergence and Accommodation

The cross point in stereovision shooting is the intersection of optical axes of the right and left cameras. The object with the cross point set is imaged at the centre of the display. In reality, there is more than one object; there are normally several objects being shot. When the observer's eyes move from the object with the set cross point to another without the cross point, the difference between the convergence and accommodation makes the observer feel fatigued. With a twin-lens camera system, there is a locus on which the difference of pixels between two images taken by the cameras is zero next to the cross point. According to geometric observations, the locus is a circle passing the centres of the camera lenses and the object of vision (or three points in all). This circle is called a horopter [2][3]. Using the concept of the horopter, the object point referred to in this paper is defined as the point where the disparity between the right and left cameras is minimal, excluding the cross point (intersection of optical axes of both cameras). Using this definition, we propose a stereovision shooting method with reduced visual burden.

3.4. Amount of Camera Motion for Object Point and Cross Point

The amount of camera motion to catch the object of vision changed using object points can be smaller than when using the cross point alone. Reduction in the amount of motion of stereo cameras may reduce the adverse effect of the changing background on the observer's eyes. The difference of the amount of camera motion between shooting a changing object of vision using the cross point and shooting it using object points is described below.

In figures 3 and 4, assume the object of vision is aligned to P and P' and then to Q (cross point) and Q' (object point). Points A, B and P is the same as points A', B' and P', respectively. Circles A, B and Q are identical to Circles A, B, and Q'. Circles A, B and P are identical to Circles A', B', and P'.
In figure 3, the following equation holds:

$$\theta_\gamma = \theta_\alpha + \theta_b = \theta_a + \theta_\beta \qquad (1)$$

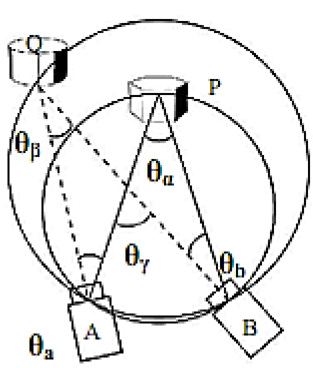

Fig. 3. Shooting at cross points

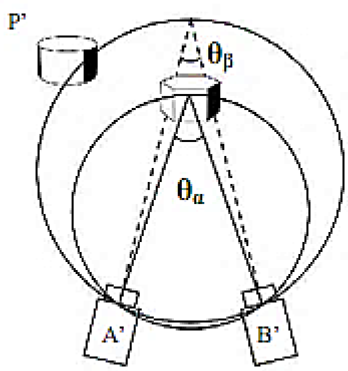

Fig. 4. Shooting at object points

The amount of camera motion from P to Q using the cross point is given by the following equation using (1):

$$\theta_a + \theta_b = \theta_\alpha - \theta_\beta + 2\theta_b \qquad (2)$$

The amount of motion (moving the object of vision from P' to Q') when using object points as shown in figure 4 is or is smaller by $2\theta_b$ from (2).

3.5. Vertical Disparity

Human eyes are set approximately 6 cm apart horizontally and almost zero vertically. This means that generally no disparity occurs vertically. The allowable range is therefore small and some reports state that stereovision is difficult to obtain with as small a gap as approximately 0.5° [1]. With the RSVS system with horizontally arranged cameras, vertical disparity could exceed the allowable range when the image is enlarged by zooming due to installation error.

4. Remote Control System

Referring to visual burden discussed in the preceding section, the authors have developed a system in which the viewer can remotely adjust the vergence and vertical disparity of the stereo cameras to reduce vertical disparity and adequately set the convergence distance and focal distance. This system has with three harmonic drive motors to adjust the direction of the cameras. With this new camera adjusting mechanism, the motors are installed from below the right and left cameras to enable them to move horizontally. The smallest adjustable distance between the cameras is 6.8 cm. The right camera is adjustable vertically to avoid the problem of vertical motion of the cameras when zooming. The cameras can be moved vertically by turning the aluminum disc after shifting its centre. It is also possible to follow and shoot a moving object.

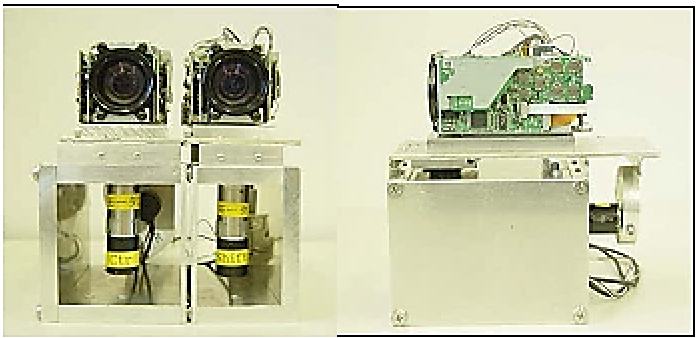

Fig. 5. Camera adjustment mechanism.

5. A New Shooting Method

The visual burden caused by using the cross method for shooting stereo images has been reduced by employing the remote control system introduced in the preceding section. The other problem of the cross method is distortion in space perception, which is also a factor of visual burden. The move-parallel method is a new stereo vision shooting method designed to eliminate distortion in space perception.

5.1. Principle of the Move-Parallel Method

The principle of the move-parallel method is described below. In figure 6, when shooting objects A and B which are equidistant from the cameras, the optical axes of the cameras pass the centres of the cameras O1 and O2. Images a1 and b1 of object A are on the line connecting object A and the camera centres. Similarly, images a2 and b2 of object B are on the line connecting object B and the camera centres. Since objects A and B are equidistant from the cameras and the right and left cameras are arrayed in parallel, ΔABO1 and Δa1b1O1 are similar. In like manner, ΔABO2 and Δa2b2O2 are similar. The segment l on the straight line connecting two points of objects A and B is perpendicular to the optical axes of the right and left cameras. Assume segment m connects the centres of the two camera lenses and segment n connects the CCD planes of the cameras, then these three segments are parallel to each other, or l // m // n. Since ΔABO1~Δa1b1O1~Δa2b2O2, the ratio of all corresponding sides is identical. Hence, AB:a1b1 = AB:a2b2. Since the scale factors are identical, the lengths of segments a1b1 and a2b2 are equal. The objects A and B have no disparity and the viewer sees the objects as being equally distant.

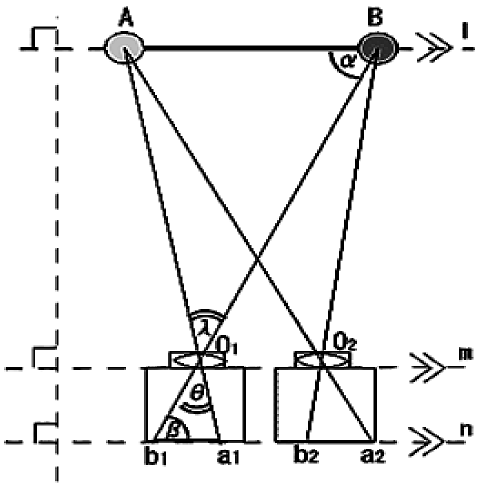

Fig. 6. Principle of move-parallel method

5.2. Merits of the Move-Parallel Method

Merits of the move-parallel method are described below referring to figures 7 and 8.

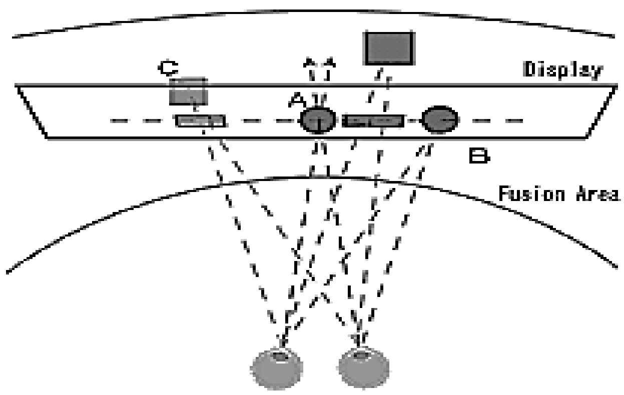

Fig. 7. Shooting using the cross method.

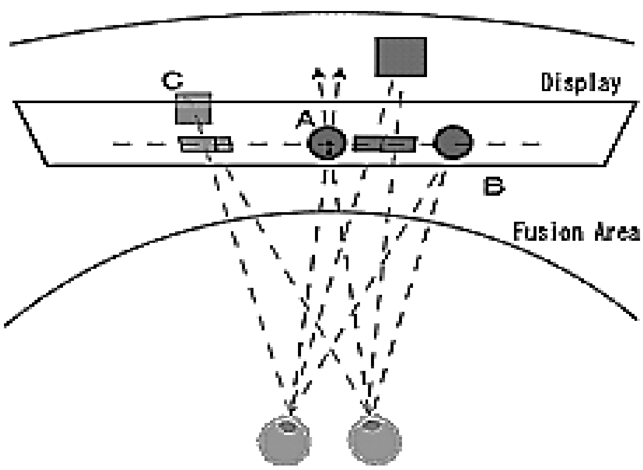

Fig. 8. Shooting using the move-parallel method.

Since the cross method uses the cross point, distortion of space perception due to the horopter, as described in the preceding section, is unavoidable. Object B on the hooter is closer to the viewer than object A on the cross point. From the positional relationship of coupling, object B sees that the object A and the viewer are equidistant from the viewpoint of disparity. For C, in contrast, distortion is generated because disparity plays a role on the screen. When using the move-parallel method for shooting, the cross point is not used and the locus of the same disparity can be drawn as a straight line starting at the fixation point. The actual positional relationship and the positional relationship of coupling are equal to obtain the correct sense of distance.

5.3. Animation Shooting Software

Currently available RSVS Versions 1 and 2 are adequate to achieve remote stereovision. The present paper proposes the move-parallel method because the purpose of the present study is the development of stereo images with a low visual burden. The authors have developed a software programme to record and replay the experiments conducted using the parallel, cross and move-parallel methods to verify the effectiveness of the move-parallel method in reducing the visual burden more than other methods through experiments with animation. The new software programme allows the user to smoothly shoot stereo images and conduct the required experiments.

6. Experiments Shooting with Stereo Cameras

Animation experiments were conducted on the move- parallel method introduced in the preceding section. Near and medium-distance perspectives were prepared for the experiments. The cross method and move-parallel method were compared for each distance perspective. By comparing the two methods, the authors have verified the usefulness of the move- parallel shooting method for the respective distance perspectives and distortion in space perception.

6.1. Outline of the Experiments

The distance between the cameras and the object was nearly identical for the two shooting methods. The motion of the object was also nearly the same. The near and medium-distance areas were all white or black to prevent diversion of the viewer's attention from the object being viewed. Images shot using the move-parallel method have a dark spot on the right-hand side of each image after translation. The dark spot was added intentionally to the images using the cross method to hide the difference between the two types of images. The subjects in the experiments were not told which method was used for the respective images. Fifty students in their early 20s participated in the experiment. After the experiment, they were asked to evaluate the ease of viewing the images, stereoscopic effects and the level of fatigue in five ranks. They briefly reported what they thought about the images and selected the best image taking all aspects into consideration from their own points of view.

6.2. Experiment 1: Verification of Near- Distance Shooting

Purpose: The purpose of the experiment was to verify which caused visual burden: the cross method (with distortion in the near-distance area where disparity tends to occur easily) and move-parallel method (no distortion).

Outline of the Experiment:

1. Disparity is set on the object
2. The object is placed 30 cm from the cameras
3. The object does not move but turns on a turn- table

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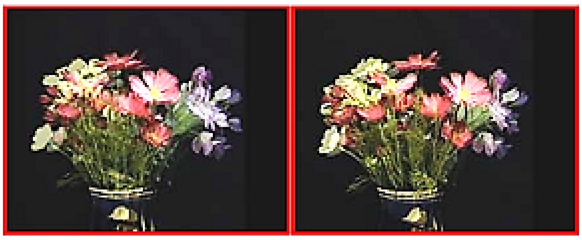

Fig. 9. Taking a picture of near-distance (left: cross method; right: move-parallel method)

Table 1: Results of questionnaire on near-distance comparison.

Near-distance	Move-parallel method	Cross method
Stereoscopic effect	3.85	3.65
Fatigue	3.25	2.5
Ease of viewing	3.95	3.35
Overall evaluation	38 (people)	12 (people)

Table 1 shows the results of the experiment. For the near-distance shooting, three times more subjects selected the move-parallel method over the cross method. Both the cross and move-parallel method provide stereoscopic effects but the move-parallel method was preferred to the cross method considering fatigue and ease of use as far as near-distance observation was concerned. Although this is because no distortion due to space perception was generated, it was known from this experiment that absence of distortion provides people with ease of viewing and less fatigue in terms of the visual burden. This indicates that the move-parallel method is fully useful in near-distance shooting of animation.

6.3. Experiment 2: Verification and Change in Disparity in Medium- Distance Shooting

Purpose: The purpose of this experiment was to verify the behaviour of visual burden caused by an increase or decrease of disparity as the object being viewed moved back and forth with disparity set to the medium distance.

Outline of the Experiment:

1. The object was placed 1 m from the cameras
2. The object was moved towards and away from the cameras in a range of 30 to 130 cm
3. Disparity was maintained at the initial position (1 m) of the subject
4. Four blocks were placed to assist in relative distance perspective. The blocks were placed in positions that did not obstruct the travel of the object

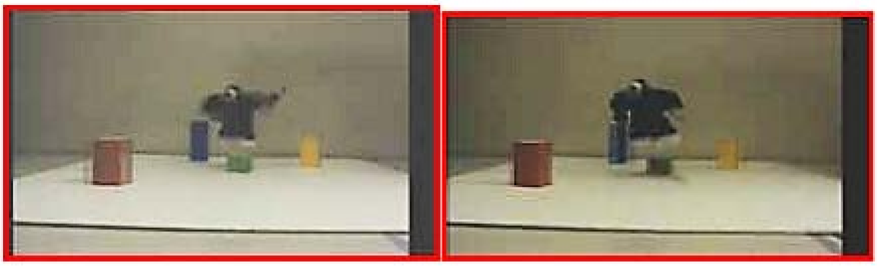

Fig. 10. Taking picture of medium-distance (left: cross method; right: move-parallel method)

Table 2: Results of questionnaire on medium- distance comparison.

Middle-distance	Move-parallel method	Cross method
Stereoscopic effect	3.65	3.85
Fatigue	2.75	3.15
Ease of viewing	3.2	3.35
Overall evaluation	23 (people)	27 (people)

Table 2 shows the results of the experiment. In medium-distance shooting, the cross method was favoured more than the move-parallel method by a small margin. Subjects who were not accustomed to stereovision must have found fusion more difficult than in near-distance shooting because of the increasing magnitude of disparity as the object approached. For medium-distance shooting, the object is located at a somewhat distant place and the angle of convergence is relatively small. For these reasons, the difference caused by distortion was not sensed much, and only a relatively small difference in fatigue and ease of viewing was noted between the two methods. The object moved only back and forth, and lateral motion (in which distortion is easily sensed) was not involved. This is another reason why not much difference was felt between the two methods. The authors believe that these are the reasons why the differences were fairly insignificant.

Conclusions

This paper presents a new technique for improving camera shooting using moving parallel method. With ordinary stereovision shooting techniques using many cameras arrayed in parallel, the convergence distance to sense the distance to the target being viewed does not match with the focal distance to obtain sharp retinal images Results of our experiments show that the move- parallel method was generally more highly evaluated for shooting near-distant images. We also found that the reactions to both methods were not very different for shooting images at medium-distance. The cross method has been considered a good shooting method because the focal distance and convergence distance are identical and the visual burden on the observer can be reduced. Our experiments have proved that the move-parallel method is as good as the cross-point method also for shooting animation at medium- distance. For these reasons, the move-parallel method can reduce the visual burden and is a better method for obtaining the correct distance perspective. Our experiments have also shown that ease of viewing and fatigue in near-distance stereovision were improved because distortion was eliminated. Based on the above findings, the move-parallel method is useful for near-distance stereovision and also for shooting stereovision images of animation as it received an evaluation similar to the cross method for medium- distance stereovision.

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