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A Face Tracking Algorithm for Multi-view Display System

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Abstract: This paper proposes a face tracking algorithm for a viewpoint adaptive multi-view synthesis system. The original scene captured by a depth camera contains a texture image and 8 bit gray-scale depth map. From this original image, multi-view images that correspond to the viewer's position can be synthesized using geometrical transformations, such as rotation and translation. The proposed face tracking technique gives a motion parallax cue by different viewpoints and view angles. In the proposed algorithm, the viewer's dominant face, which is established initially from a camera, can be tracked using the statistical characteristics of face colors and deformable templates. As a result, a motion parallax cue can be provided by detecting the viewer's dominant face area and tracking it, even under a heterogeneous background, and synthesized sequences can be displayed successfully.

Keywords: Face tracking, Multi-view synthesis, Depth data, Extraction face region, Characteristic points of face, Multi-view display system

1. Introduction

People endlessly desire to see more realistic and life-like images. Accordingly, more study is needed to develop 3D image-contents generation technology that reflects reality and natural features to the maximum is the field. A stereo system to provide a stereoscopic view only to one viewer requires images in two planes for the viewer, so that the MPEG or H.261, H.263 and other similar systems, which are existing video compression standards, can be applied to processing images. On the other hand, in a stereo system, because the viewpoint is fixed to a single place, the viewer cannot observe 3D images or feels considerable fatigue when he/she is positioned departing from the viewing area or his/her two eyes cannot be fixed precisely to the viewing area due to the structure of the human body. The multi-view display technique to give a natural stereoscopic view to the viewers is the currently most efficient technique for representing 3D images. On the other hand, when a multiple camera is used to obtain multi-view image contents, there are errors resulting from additional image processing depending on the use of multiple cameras. Furthermore, because of the limits on the number and spacing of cameras, a discontinuity can be encountered when the viewpoint moves and the amount of data increases. In this study, unlike the existing multi-view image processing technology using multiple cameras, a depth sensor is provided on a single camera, which is referred to as a depth camera, that can obtain the RGB texture and depth values simultaneously [1]. In addition, two techniques are employed. The first is to generate images for two or more viewpoints using the obtained depth values. The second is to artificially generate images corresponding to an intermediate viewpoint from the left and right images.

In this paper, the face tracking technique was newly proposed as a user interface to generate stereo images corresponding to a total of 11 viewpoints and display the images matching the viewer’s viewpoint among the generated images, depending on the viewer’s viewpoint. The proposed technique consists of detecting the viewer’s position in the current frame, then defining on the screen various viewpoints for 3D objects and spaces according to the detected viewpoint, followed by representing the corresponding 3D images depending on the changes in the

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viewpoint using a display device. Therefore, the viewer can observe stereo images corresponding to any viewpoint through a stereo display to which his viewpoint is fixed.

In this paper, for face tracking, the color information-based method was used. The method of face detection, using the color information allows the facial characteristics to be obtained easily and rapidly, and can be implemented in real time because the amount of computation can be reduced compared to other conventional methods.

The method of using the color information, however, is sensitive to the external environment, such as illumination. The method also disadvantageously detects all color distribution similar to a face. Therefore, this study aims to implement a system and method to ensure more robustness while satisfying the real-time precondition.

The outline of system will be introduced in chapter 2. Chapter 3 describes the process of face detection and the method of face tracking. Chapter 4 assesses the result of the proposed system and simulation. Chapter 5 reports the conclusions of this paper and proposes future research directions.

2. Synthesis of a Stereo Image using Depth Information

Generally, the most ideal method for displaying 3D images is a holographic video [2]. The holographic video can provide a stereoscopic view to many viewers simultaneously and does not cause fatigue. With the current technology, however, it is impossible to implement a real time holographic video system. The stereo system and multi-viewpoint system are real-time 3D display systems that are currently and generally used. The stereo system synthesizes left and right images obtained by two cameras to one sheet of 3D images and displays the image. In this case, the viewer can feel a stereoscopic depth cue by means of the disparity of the left and right eyes. When the viewer's position changes, however, the image displayed (Fig. 1) is not a stereo image corresponding to the changed viewpoint, but a stereo image corresponding to the viewpoint before the change. That is, it is impossible to provide a stereo image by a motion parallax cue.

On the contrary, the multi-view image display can display a stereo image pair corresponding to the viewer's viewpoint. Therefore, the multi-view system can provide both the stereoscopic depth cue of the stereo system and motion parallax cues depending on the viewer's motion. Multi-view images can be displayed in two ways. The first is to display multi-view images simultaneously [3]. This display may serve multiple viewers. The freedom of movement, however, is restricted and the motion parallax is not continuous but discrete. The other way of a multi-viewpoint system provides only a single stereo-image pair to a single viewer (Fig. 1). In this system, stereo images are first obtained using two cameras. After transmitting the obtained images, multi-view stereo images are generated by a geometric transformation with a pair of stereo images. In the multi-view display system, the stereo images are displayed, corresponding to the viewer's viewpoint among the generated multi-view images. Fig. 2 shows a schematic diagram of the multi-view image display system proposed in this paper. Studies similar to the aforementioned one have been actively performed by the recent PANORAMA project in Europe [4].

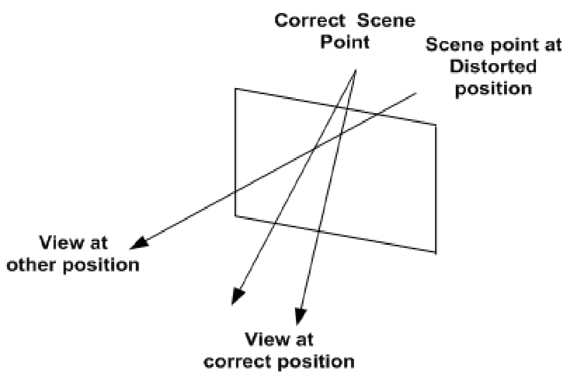


Fig. 1. Geometric distortion in a stereo system.

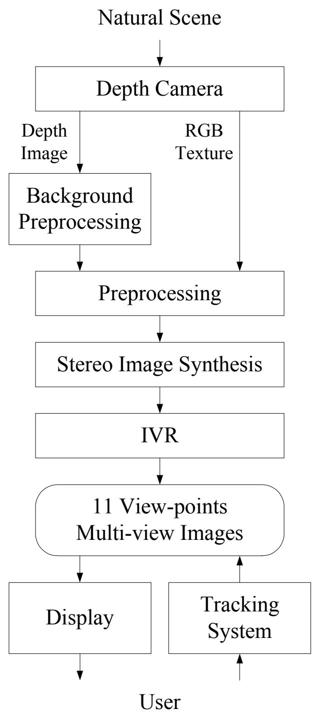


Fig. 2. Multi-view Display system.

The system first obtains 8-bit gray scale images with RGB texture images and depth values using a depth camera (Z-cam), as shown in Fig. 3. The system then generates stereo images from the obtained images. In this case, the obtained RGB texture images are defined as left images and the depth values are converted to disparity values to generate the corresponding right images. The right images are generated with the converted disparity values.

From a geometric transformation, such as rotation, translation and the like, multi-view stereo images are generated by an intermediated viewpoint rendering technique, such as 3D-warping, corresponding to 11 viewpoints in the horizontal direction. Finally, the face

(a) RGB teture

(b) Depth data

Fig. 3. Depth camera output.

tracking technique proposed in this study was used to display stereo images corresponding to the viewer's viewpoint among the generated multi-view stereo images. The images in the multi-view system were obtained from a virtual camera based on the images obtained by a depth camera. A technique for generating geometrically accurate images is required to obtain accurate images from such a virtual camera. The method proposed in reference [5] was used as a technique for generating multi-view stereo images using RGB texture and depth values. The technique for tracking the viewer's face is proposed to display stereo images corresponding to the viewer's viewpoint after generating multi-view stereo images using the method [5] in this study.

General face tracking is influenced significantly by the external environment, such as the surrounding environment or illumination. From the errors caused by such an external environment, incorrect viewpoints are transferred to the multi-view display system, and erroneous stereo images caused by the errors are displayed. Therefore, a face tracking technique is proposed in this paper.

3. Face tracking system

The real-time face tracking system has many applications to HCI (human computer interaction). Here, face tracking is studied to carry out segmentation as a precondition for recognizing the user's face, in addition to simply matching the attention of a computer to the user's face. This is an essential element technology to enhance the recognition accuracy. In the recent trend of face tracking, Wang and Brandstein proposed a face tracking based on the frame difference resulting from head motion assuming that the head boundary is oval-shaped and the second order derivative is the largest on the neck part [6]. On the other hand, the face area may not be separated accurately by a moving background resulting from camera movement, etc., and the assumption of an oval-shaped face may be broken when the face is partially covered or the relevant person wears a hat. Hager and Belbumeur proposed a tracking method using a correlation coefficient method by modeling a variety of illumination situations using basis images [7]. In this method, however, the initial positions for tracking must be set up. Because basis images are made for a clean front face, the images are sensitive to partial covering or changed face directions. McKenna and Gong used a method for detecting areas with motion to find a front face [8]. This method is also influenced by moving background areas resulting from camera movement and partially covered faces. Quian used colors and proposed a technique for face tracking with a probability approach by reducing the second dimensional problems to one dimensional problems using color function values projected onto the x and y axes, respectively, to increase the speed [9]. Because this method simplifies the problems too much, there are many restrictions and no comments about color model adaptation to environmental changes. Yang and Waibel proposed face tracking based on skin color filtering [10]. They introduced a method for face color model adaptation, but could not solve the problems by momentary illumination changes because the method was implemented by simply accumulating statistical values.

As observed from the aforementioned methods, in real-time face tracking, while satisfying the real-time condition, the application scope may narrow or robustness may not be ensured. Therefore, this study aims to implement a system that can ensure more robustness while satisfying the real-time precondition. The information that can be obtained more rapidly and most easily from the images is the color values. This information contributes to efficiently reducing the number of computations by a computer and is used to detect face areas. When using the color information, however, there are problems caused by illumination or surrounding environmental changes. To solve such problems, an accurate face area is verified using facial feature extraction and geometric features of the face after extracting the face areas. For the verified face region, the face tracking is based on statistical color modeling and deformable templates.

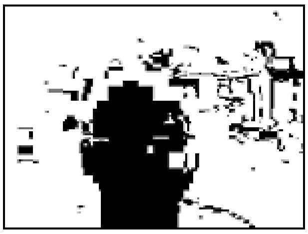
3.1 Technique of extracting face region by color information

The input images obtained from cameras for obtaining the viewer's face provided on the display device are color images of the size (320×240) including color information.

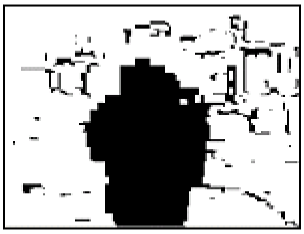
The face region extraction technique using color information is applied after converting the input image from RGB to YCbCr for color space. First, only the regions with skin color values are extracted through color segmentation for the components of Cb and Cr among the information of Y, Cb and Cr in the input images. To use the skin color values, only a part of the skin color are extracted from the images to find a histogram for the range of values of Cb and Cr occupied by the skin color. The range occupied by skin color can be determined statistically by applying such a histogram to a plurality of images. The selected range of Cb and Cr found in this study are described in the following equation.

$$f(x,y)=\begin{cases}0 & if\,(137<Cb<152)\cap(123<Cr<137)\\ 255 & otherwise\end{cases} \tag{1}$$

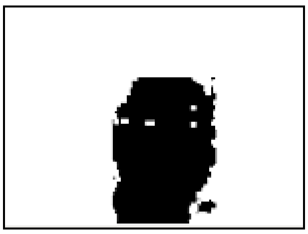
Fig. 4(a) shows the resulting images of the input images through color segmentation. A fine noise shape can be seen in Fig. 4(a). To eliminate such noise, the opening operation was first performed among the morphological filter [11]. Fig. 4(b) shows the resulting images of applying an opening operator to the images of Fig. 4(a). Next, horizontal scanning was performed. The number of pixels with a value of zero in the horizontal direction was counted and the pixel values were all adjusted to 255 for the area whose result has a value less than the threshold value. Here, the threshold value was set to half of the maximum value assuming that the horizontal size of the face region is a half of the whole image. This assumption was made because the viewer's position is defined more or less to be in front of the display device in most cases. When scanning in the horizontal direction was complete, scanning was carried out in the vertical direction. After scanning was complete, the images shown in Fig. 4(c) were obtained.



(a) Color segmentation



(b) Noise elimination



(c) Face region

Fig. 4. Extracting the face region.

3.2 Detecting characteristic points of face

To eliminate another candidate, the skin color regions surrounding the face region, a decision was made to determine if the detected candidate skin color region is a face area. To check the face region, the characteristic points of a face were detected. The difference between the environment for extracting a general face region and the environment for this study is that a viewer whose face will be extracted always wears 3D polarized glasses. Therefore, it is difficult to determine an accurate face region with the existing general face area extraction and characteristic point extraction technique, in which the eyes are the characteristic points. In this case, incorrectly reconstructed images may be represented because of the delivery of an erroneous viewpoint.

In this paper, to overcome such restrictions, the characteristic points were detected through geometric features and templates of a face. First, to extract the face region and detect the characteristic points, the object to be extracted, i.e. the viewer's face size and position information, was stored. Such key information for the viewer was used as information for extracting only the viewer's key face region when candidate regions exist, such as the face regions other than the viewer or skin color areas for the hands.

Templates were used to detect the characteristic points of a face. Because the viewer wears polarized glasses in this paper, it is impossible to detect the eyes. Therefore, the template for a mouth shown in Fig. 5 was designed.

■ = -5 □ = +5

Fig. 5. Mouth template 50×16.

The matching value (MV) was proposed to use it as a detection measure of a mouth. The MV can be considered as a type of correlation between a black and white image ranging from 0 to 255 and the mouth template with a value between -5 and 5.

$$MV(m,n)=\frac{1}{X_t\times Y_t}\sum_{x=0}^{X_t-1}\sum_{y=0}^{Y_t-1}(E[x][y]\times I[x+(m-8)][y+(n-10)])$$

$$8\le m<X_i-8,\quad 25\le n<Y_i-25 \tag{2}$$

where $E[x][y]$ represents the mouth template used, X_t and X_t indicate the vertical and horizontal sizes of the mouth template, respectively. $I[x][y]$ represents the face region of the input images, and X_i and Y_i are the vertical and horizontal sizes of the face region detected from the input images, respectively. The maximum value of MV was generated when there was pattern matching to the template in the face region. When a mouth is detected, the location of the polarized glasses conforming to the face structure was estimated based on the mouth location. After setting the location of the estimated polarized glasses, the presence/absence of the polarized glasses was determined as a variance value and a pixel value in the region of the polarized glasses. The reason is that when the viewer wears polarized glasses, the variance becomes small because the pixel values do not significantly change compared to the case when the viewer does not wear polarized glasses. Because polarized glasses are black, the pixel value is smaller compared to the other areas. For the threshold value of the variance, the optimized value was selected empirically. In this system, after extracting the mouth and polarized glasses, which are the characteristic points of a face, the location and the distance between the extracted mouth and polarized glasses was measured. When the measured values were compared with the geometric features of the face and a large error was found, it was confirmed to be a candidate skin color region, not a face region. By carrying out the process repetitively, an accurate viewer's face, not a candidate skin color region, such as the hands or another person's face, could be extracted.

3.3 Face Tracking

After extracting the face region, the extracted face region is defined as a key viewer. Subsequently, face tracking is performed for the key viewer. In this paper, for face tracking, the method using color-based statistical color modeling and the deformable templates is used [12]. The face region shows different features from the background area other than the face region. The main color of the face region is composed of skin color and facial hair color, and the background region is composed of other different colors. After finding the variance and deviation for the face region, the face region is separated from the background while finding the variance and deviation for the pixels at a specified location in the current frame. Through statistical modeling of the skin color and the facial hair color of a face, the main two colors of a face region, can be represented by the following equation.

$$p(x \mid w_i) = \alpha_{i1} N(u_{i1}, C_{i1}) + \alpha_{i2} N(u_{i2}, C_{i2}) \tag{3}$$

where $p(x \mid w_i)$ is a probability density function value that x belongs to the w_i region. x is the pixel value of the current frame and if = 1 in w_i, w_i means a face region that is a front image. i = 2 means a non-face area that is a background image. $N(u, C)$ represents a Gaussian function. u and C are the mean and covariance of the Gaussian function value, respectively. α_{i1} and α_{i2} are the weight functions of the Gaussian function. Such function values of $p(x \mid w_i)$ reflect where a specified pixel value is located. In addition, it is possible to find an area containing the pixels of the face region as many as possible using the deformable template. That is, in Eq. (4), the location value of the template is the location of a face when the energy value is a minimum.

$$f(\Re) = \sum_{r \in \Re} \log\left(\frac{p(x_r \mid w_2)}{p(x_r \mid w_1)}\right) \tag{4}$$

where r is a pixel of the template region $\Re$,and x_r is a pixel value. A face region is searched while adjusting the deformable template region size, where the energy of $f(\Re)$ is minimized. The deformable template is efficient as a method for analyzing frame based images.

4. Implementing a system and results of the test

4.1 Implementing a system

The implemented system displays stereo images corresponding to a key viewer's location after recognizing the location depending on the key viewer's face. Fig. 6 shows the display system implemented in this paper. After receiving one sheet of texture image obtained from a depth camera and one sheet of 8-bit image with a depth value, the system tracks the face from the viewer's image obtained in real time from the camera equipped on the display, and displays the tracked face image.

To display stereo image corresponding to any viewpoint, it is essential to know the viewer's viewpoint, and for this purpose, two steps involving face region extraction and tracking are carried out. Face region extraction was carried out for the image of approximately 20 frames initially input. For accurate face region extraction, the candidate skin color regions were eliminated using the characteristic point detection and geometric features of a face. After extracting the accurate face area, face tracking was carried out using a color modeling and deformable template of the extracted face area. After finding an optimum face region for each frame, a viewpoint in the current frame of the face region was generated according to Eq. (5).

$$View\ Point = (VP_{cur} - VP_{first}) / (VP_{total} / p) \tag{5}$$

where VP_{first} indicates a location of the first face region. This is a reference location of a viewer for 20 frames after inputting an image. VP_{cur} indicates the location of the current face, and VP_{total} indicates a horizontal size of an input image. In the implemented system, the input image obtained from the camera of the display device is divided into 11 areas to display a multi-view image depending on the changes in the viewer's 11 viewpoint (=p). When the

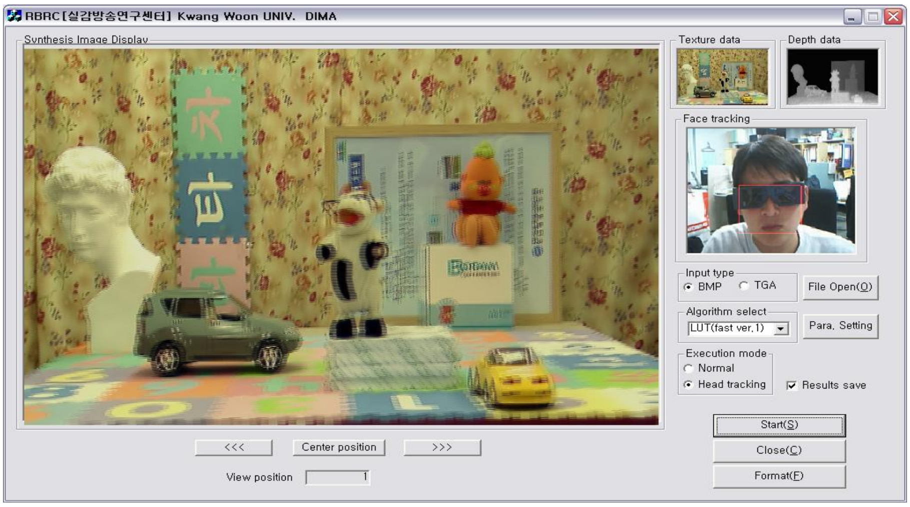


Fig. 6. Multi-view display system.

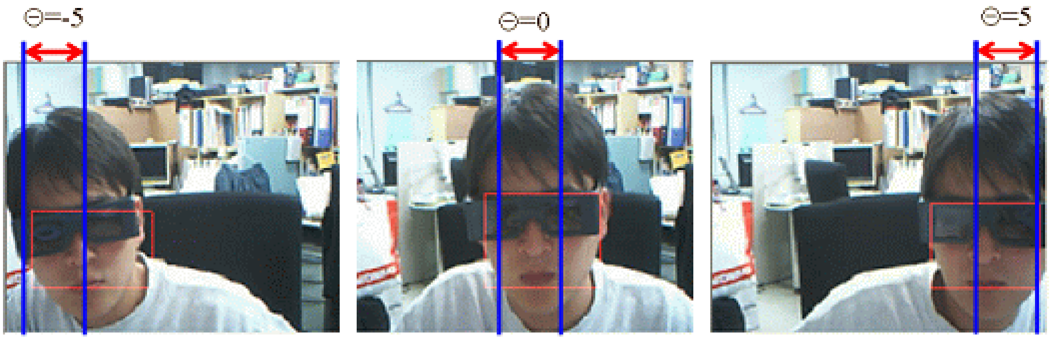
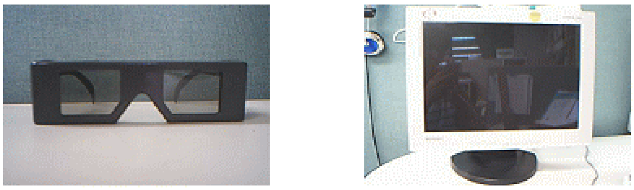


Fig. 7. Viewer's Viewpoint.



(a) (b)

Fig. 8. (a) Polarized glasses, (b) 3D glasses-type monitor.

viewer is positioned in the center, it is defined as θ=0. When he/she is positioned to the most left, it is defined as θ=-5. When the viewer is positioned to the most right, it is defined as θ=5. All 11 views between the aforementioned locations are defined. As shown in Fig. 7, the viewer's viewpoint is located on a specified area, θ is transferred to the multi-view image generator and 3D stereo images are then displayed. To view the 3D stereo images, polarized glasses and 3D glasses-type monitor can be used, as shown in Fig. 8.

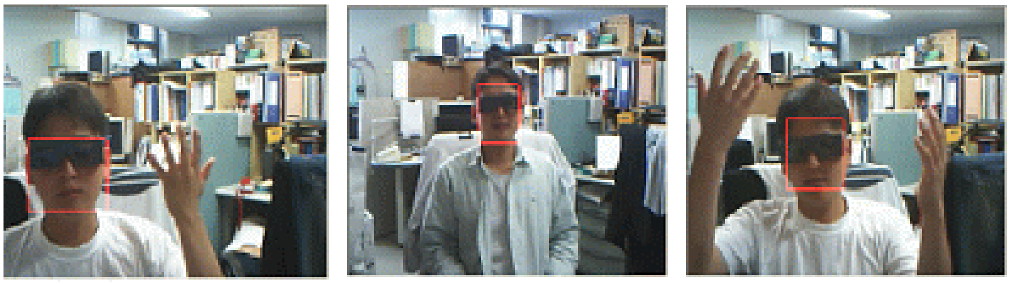
4.2 Experimental Results

Table 1 lists the test environment used in this paper. The image with a size of 320×240 is received from a camera equipped on the display device and the viewer's face is checked in real time using the proposed face tracking technique. The stereo image corresponding to the viewer's viewpoint is also reconstructed as any proper

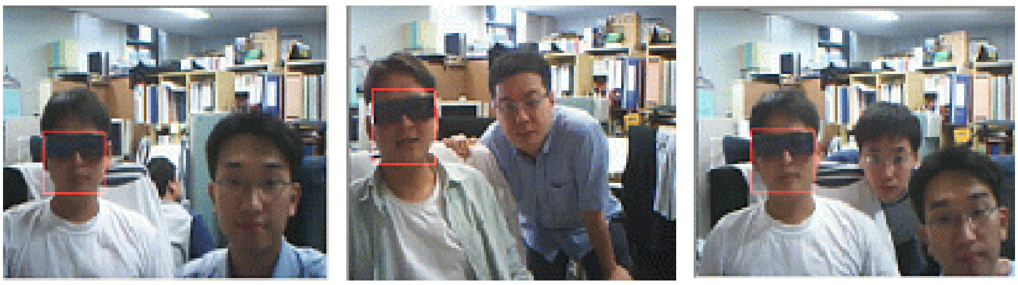
Table 1. Test environment.

OS	Window XP
PC	P-4 2.8 GHz
PC camera	Sensor: 1/3 CMOS
	Resolution: 640×480
	FPS: 15 frame/sec
Implementation tool	with level *l* and type *f* in the previous GOP
Input image	320×240 size, RGB 24bit, 10 frame/sec

(a) Movement



(b) Elimination of the candidate skin color



(c) Multi viewer

Fig. 9. Face Tracking Results.

viewpoint images using RGB texture images with a size of 720×480 and the depth value. Figs. 9 and 10 show the result of the test using the technique proposed in this paper. Fig. 9(a) shows an accurate face tracking result depending on the left and right movement. Fig. 9(b) is the resulting image showing no influence on the skin color other than the viewer's face, even though there are hands or surrounding skin color areas. Fig. 9(c) shows the result of tracking only a key viewer when another faces appears on the image.

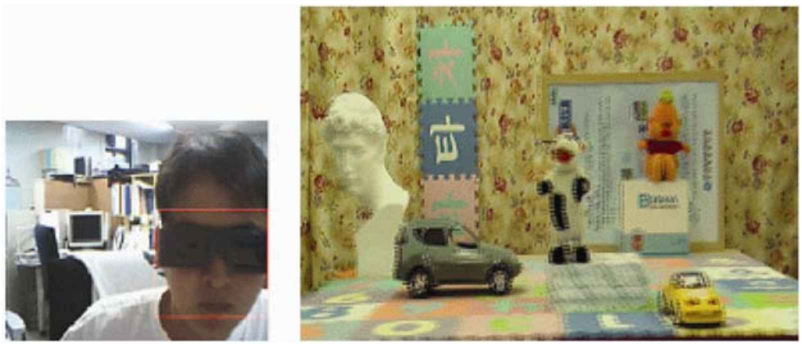
Fig. 10 shows the displaying stereo images corresponding to each viewpoint of a viewer when their face moves to the left or right. The results in Fig. 10 were checked using the 3D monitor and the polarized glasses shown in Fig. 8. As a test result, it was possible to successfully track the viewer's face accurately in real time in the interface to display stereo images corresponding to any viewpoint, as shown in Figs. 9 and 10.

5. Conclusion and Future Work

In this paper, stereo images with 11 viewpoints in total, one sheet of a texture image and the depth value image of a texture image could be obtained using a depth camera without using several cameras to display multi-view images. To display the images obtained depending on the viewer's viewpoint, a new technique was proposed to detect a face area from the input image obtained from the camera equipped on the display. The proposed technique accurately tracked the detected face region in real time. In a general office environment, the images are affected by the complicated background behind the user's face as well as external light. Therefore, it is impossible to track a face accurately and perfectly in real time using the color modeling method only. In addition, even FaceItTM, which is has excellent performance for face feature extraction and face recognition and is available from Identix Co., is influenced by the human race type and illumination type in the face feature extraction. As described above, it is very difficult to overcome all the limits in the color model but the proposed technique showed good performance in the interface for displaying images corresponding to any viewpoint in a multi-view image display system, in real time. Therefore, more study will be needed to research and develop new techniques that are more robust to the external environment and can be implemented in real time.

(a) Result 1 (Θ = -5)

(b) Result 2 (Θ = 0)



(c) Result 3 (Θ = 5)

Fig. 10. Multi-view display results.

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