PAPER *Special Issue on Machine Vision Applications*

Region Extraction with Chromakey Using Stripe Backgrounds

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SUMMARY In this paper, we propose a new region extraction method with a chromakey technique using a two-tone striped background. A chromakey compositing is a technique for separating actors or actresses from a background, and then compositing a different background. The conventional chromakey technique usually uses an unicolored blue or green background, and has a problem that one's clothes are regarded as the background if their colors are same with the background's color. Therefore, we use two-tone striped background and utilize the adjacency condition between two-tone striped areas on the background to extract the foreground regions whose colors are same with the background. The procedure of our proposed method consists of four steps: 1) background color extraction, 2) striped region extraction, 3) foreground extraction, and 4) image composition. As to the background color extraction, the color space approach is used. As to the striped region extraction, it is difficult to extract striped region by a color space approach because the color of this region may be a composite of two background colors and different from them. Therefore, the striped region is extracted from adjacency conditions between two background colors. As to the foreground extraction, the boundary between the foreground and the background is detected to recheck the foreground region whose color is same as the background, and the background region whose color is same as the foreground. To detect the region whose color is same as the background, the adjacency conditions with the striped region are utilized. As to the image composition, the process that smoothes the color of the foreground's boundary against the new background is carried out to create natural images. The validity of proposed method is shown through experiments with the foreground objects whose color is same as the background color.
key words: *chromekey, region extraction, stripe, color segmentation*

1. Introduction

The composition of images [1] has significant consequences to creative designs such as cinema films, magazine covers, promotion videos, and so on. This technique can combine images of actors or actresses in a studio and those of scenery that is taken in another place. The foreground must be segmented from the background when compositing images, and there are a lot of studies about image segmentation [2], [3], e.g. pixel-based segmentation, area-based one, edge-based one, and physics-based one. For example, the snakes [4] is a popular technique based on the edge detection. However, the automatic methods for the arbitrary background have not been developed to a practical level. Additionally, robust methods are needed especially for a live program on TV [5], [6]. A simple approach that takes a difference between the image that contains new foreground objects and the known background image is proposed [7]. This method extracts foreground objects based on an arbitrary threshold value of difference between two images. However, there are several limitations, e.g. a camera cannot move, the lighting condition must be same when the known background image and new images are taken, and so on. Composite images by this approach are also prone to jagged.

Therefore, an image composition method called chromakey that can segment human objects from a uniform color background and superimpose them with another background electronically has been proposed. This technique has been used for many years in the TV and the film industry. The conventional chromakey technique uses background whose color is solid blue or green, and extracts the region in images whose colors are not same with the background. Although this can be successfully used, several problems associated with this method still need a solution.

As to the camera motion, Shimoda *et al.* propose the method that the background image alters accordingly as the foreground image is altered by panning, tilting, zooming and focusing operations of the camera [8]. This method is the fundamental technique of virtual studios [5], [6].

As to the lighting condition of the foreground, Debevec *et al.* achieve realistic composites between a foreground actor and a background environment with a sphere of inward-pointing light focused on the actor [9]. This system can create the arbitrary color and intensity to replicate a real-world or virtual lighting environment, although the actor cannot move freely in a large area because he must stay inside the spherical studio whose size is far smaller than the ordinary studios.

As to the extraction of the background color, Mishima proposes a parameter decision method of a key (alpha) value that indicates the background color by considering a polyhedric slice in the color space [10].

Manuscript received March 27, 2003.
Manuscript revised July 29, 2003.
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The estimation of alpha value that is the proportion in which two colors mix to produce a color at the boundary is the most important problem in the composition of images. Therefore, Mitsunaga *et al.* propose the human assisted segmentation method for an arbitrary background that leaves little work to the operator [11]. However, this method is not suitable for the live, because it cannot extract the foreground object automatically in real time.

Ruzon and Tomasi propose a new estimation method of alpha value in natural images whose boundaries involve natural objects by using coarse knowledge of the boundary's location [12]. Chuang *et al.* propose a new Bayesian framework for extracting a foreground element from a background image by estimating opacity for each pixel of the foreground elements [13]. Hillman *et al.* propose a technique for segmenting objects with soft edges from motion picture resolution images using limited human interaction, and extend this technique to allow classification of subsequent frames with little or no further user-input [14]. These methods aim at extracting natural images with intricate boundaries such as trees, hairs, furs, water, smoke, and so on. These studies construct algorithms for exact estimation of alpha value by several approaches.

As to the transparent foreground objects, Zongker *et al.* develop a system capable of accurately compositing surfaces that are truly transparent and also reflective and refractive, such as a colored glass [15]. This method requires multiple artificial backgrounds and a static foreground when images are taken.

One of the most critical and unsolved problems is that if one's clothes and the background have the same color, the former is regarded as the latter (Fig. 1(a)). Smith and Blinn propose the blue screen matting method that allows the foreground object to be shot against two backing colors [16] (Fig. 1(b)). This method can extract the foreground region whose colors are same with the background color. However, this multi-background technique cannot be used for live actors or moving objects because of the requirement for repeatability. Previous studies about the exact estimation of alpha value [12]–[15] also cannot treat this same color foreground problem.

On the other hand, the region extraction methods without particular backgrounds are proposed. Kawakita *et al.* propose the axi-vision camera that has up-ramped and down-ramped intensity-modulated lights with an ultrafast shutter attached to a CCD probe camera [17]. This system can obtain the range information about the distance between the camera and the objects in the images and extract the object by using the range information. However, this system has the problem that the accuracy of the range information depends on the intensity of reflecting lights. Therefore, it is very difficult to extract objects that have fine structures and little intensity of reflecting lights such as black hairs. This camera cannot extract these objects at the same level as the chromakey.

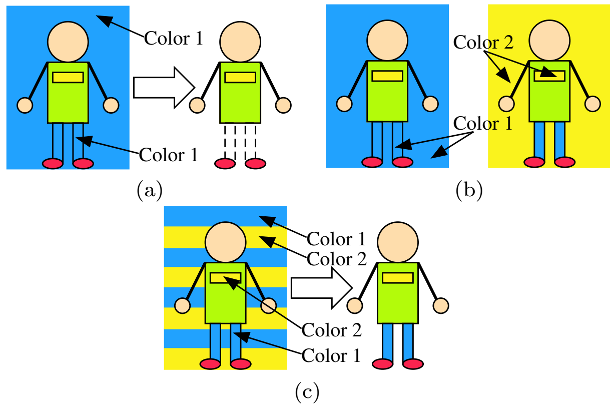


Fig. 1 Region extraction with chromakey techniques using several types of the backgrounds. (a) Unicolor background. (b) Multi background [16]. (c) Striped background (Our proposed method).

In this paper, we propose a new method that makes it possible to segment objects from a background precisely even if objects have the same color as the background, by using two-tone striped background (Fig. 1(c)). In our method, the adjacency condition between two-tone striped areas on the background is utilized to extract the foreground regions whose colors are same with the background. Our method does not need two shots, and can treat live actors or moving objects in principle. The threshold values for a color extraction can also be adjusted automatically to improve the robustness against the change of the lighting conditions.

2. Chromakey with Stripe Backgrounds

Chromakey means "chroma-key" or "color-key". The color $I(u,v)$ of a compositing image at a pixel (u,v) is defined as:

$$I(u,v) = \alpha(u,v)F(u,v) + (1-\alpha(u,v))B(u,v), \quad (1)$$

where $F(u,v)$ and $B(u,v)$ are the foreground and the background color, respectively, and $\alpha(u,v)$ is the alpha key value at a pixel (u,v) [1].

The color at a pixel (u,v) is same with the foreground when $\alpha(u,v)$ equals to 1, and that is same with the background when $\alpha(u,v)$ equals to 0. In other words, the region extraction with a chromakey technique is the problem of the alpha key extraction at each pixel (u,v).

The alpha key value is ordinary estimated by a color space approach, e.g. [10] and an image space approach, e.g. [4]. However, the foreground cannot be extracted by only using these two approaches when the colors of foreground objects are same with that of the background. The same is true for the two-tone striped backgrounds that we propose. Therefore, the boundaries where the color of the striped background changes are utilized for detecting the foreground region whose color is same as the background.

The procedure of our proposed method consists of four steps:

1. background color extraction
2. striped region extraction
3. foreground extraction
4. image composition

Note that precise estimation of alpha value around the boundaries between the foreground and the background is not executed and alpha value is set 0 or 1 in this paper.

2.1 Background Color Extraction

After obtaining an image with the two-tone striped background, a median filter is used for the noise removal. The difficulty of setting threshold values for backgrounds' color extraction can be reduced to remove small noises in the background.

Candidate regions of the background are extracted by using a color space approach. Let C_1 and C_2 be the colors of the two-tone background in acquired images from the camera, and R_1 and R_2 be the region whose color is C_1 and C_2, respectively. R_i $(i = 1, 2)$ is defined as:

$$R_i = \{(u, v) | F(u, v) \in C_i\}, \tag{2}$$

where $F(u, v)$ is the color of an image at a pixel (u, v).

It occurs frequently that the color of the background is similar to that of the foreground object, though they can be divided in the color space. For example, the color of the blue background is very similar to the color of blue denim pants or jackets that a number of people usually wear. Therefore, for setting C_i systematically, we define $C_{f,i}$ $(i = 1, 2)$ explicitly as the foreground color that is similar to that of the background. Accordingly, C_i is expressed as follows:

$$C_i = C_{b,i} \cap \overline{C_{f,i}}, \tag{3}$$

where $C_{b,i}$ $(i = 1, 2)$ is the color of the background. The human operator can decide the threshold values easily to configure both $C_{b,i}$ and $C_{f,i}$ (Fig. 2).

$C_{b,i}$ and $C_{f,i}$ $(i = 1, 2)$ are extracted by thresholding process in the RGB color space, respectively. These colors are expressed as the region surrounded by the planes in the RGB color space (Fig. 3).

The planes' equations are decided by the human operator in advance by using the images in which only the striped background exists. Each plane can move in parallel to adjust the lighting condition. However, the change of the lighting condition cannot be detected exactly from all the areas in the image, because the change of the color in the image depends on the foreground objects' colors. Therefore, the average brightness of two regions in the background (reference area in Fig. 2) is utilized. The reference area is the region except the middle area of the image where the probability that the foreground objects exist is very high. The lighting condition can be estimated by using these areas with free of influence from the foreground objects' colors. From the result of the rough grouping of C_1 and C_2 in the HSI color space, the average values of (r, g, b) in R_1 and R_2 in the reference area can be calculated respectively. To compare the initial values of (r, g, b) with the present values, each plane changes adequately.

From these procedure, R_1 and R_2 are extracted, respectively (Fig. 4(a)(b)).

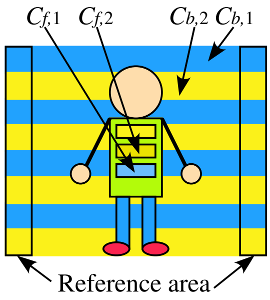


Fig. 2 Color of the image.

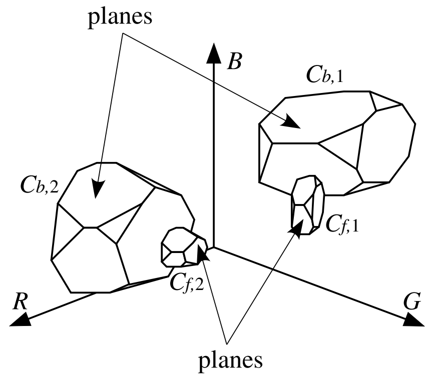


Fig. 3 RGB color space

2.2 Striped Region Extraction

The background mainly consists of the three regions: R_1, R_2, and R_3. R_3 is the intermediate region between R_1 and R_2 (Fig. 4(b)). It is difficult to extract R_3 by a color space approach because the color of R_3 may be a composite of C_1 and C_2 and not either C_1 or C_2. Therefore, R_3 is extracted not from the color space approach but from adjacency conditions in our method.

Here, let C_3 be the color defined as follows:

$$C_3 = \{F | F \notin (C_1 \cup C_2)\}. \tag{4}$$

C_3 is the color of R_3 or that of the foreground. The

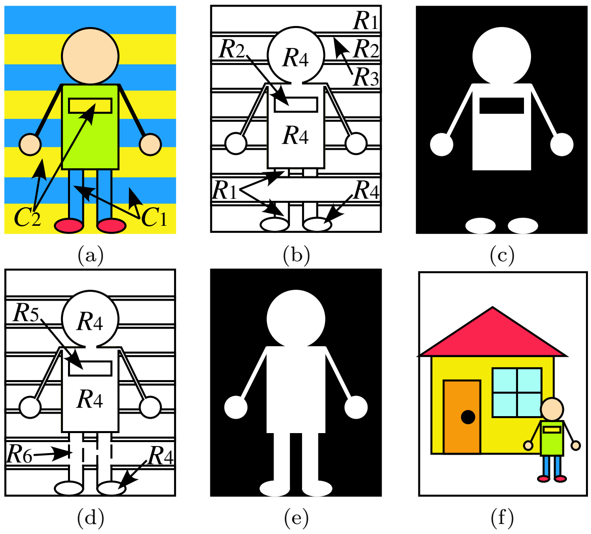


Fig. 4 Region extraction. (a) Original image. (b) Region segmentation without using the information of the striped area. (c) Foreground extraction without using the information of the striped area. (d) Region segmentation by using the information of the striped area. (e) Foreground extraction by using the information of the striped area. (f) Image composition.

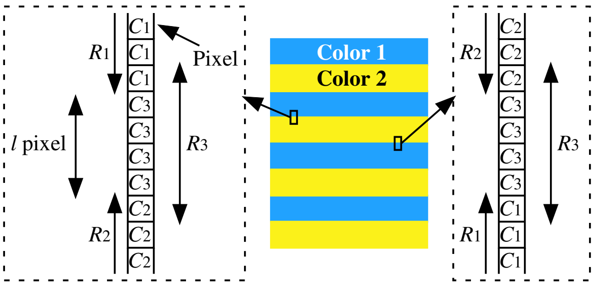


Fig. 5 Detection of R_3 region

difference between R_3 and the foreground is that R_3 contacts with both R_1 and R_2 according to the following rule. In the case of horizontal stripe, the color of the upper and lower region of R_3 differs from each other. Therefore, R_3 is expressed as follows:

$$\begin{aligned} R_3 = \{&(u,v),(u,v+1),\ldots,(u,v+l+1)| \\ &(u,v+1)\in C_3,\ldots,(u,v+l)\in C_3, \\ &\big((F(u,v)\in C_1, F(u,v+l+1)\in C_2) or \\ &(F(u,v)\in C_2, F(u,v+l+1)\in C_1)\big)\}, \end{aligned} \quad (5)$$

where l is the total number of the pixel whose color is C_3 in the vertical direction (Fig. 5). The size of l mainly depends on the resolution of the image. This equation means that each R_3 region has a certain width (l), the color of each R_3 region is not C_1 and C_2, and each R_3 region is surrounded by R_1 and R_2 in a horizontal direction. R_3 regions can be extracted exactly by using this region-based approach compared to the color segmentation approach.

Consequently, the background region of the image R_{bg} is obtained.

$$R_{bg} = \{(u,v)|(u,v)\in(R_1\cup R_2\cup R_3)\}. \quad (6)$$

After searching R_3, the foreground region R_4 is determined as follows:

$$\begin{aligned} R_4 &= \{(u,v)|F(u,v)\in C_3,(u,v)\notin R_3\} \\ &= \{(u,v)|(u,v)\notin R_{bg}\}. \end{aligned} \quad (7)$$

In the foreground region R_4, there exist the areas whose colors are not C_1 nor C_2, but are actually the background region. This is because the setting of the background colors C_i ($i=1,2$) cannot be executed impeccably and the image noise unavoidably exists. These areas are isolated points or isolated areas whose size is very small in most cases. Therefore, isolated areas whose size are under s_{max} pixels in R_4 are removed and regarded as the background.

In this procedure, all regions whose colors are same as the background are extracted as the background. An example of extraction error is shown in Fig. 4(c). They must be corrected in the next step.

2.3 Foreground Extraction

The boundary between the foreground and the background is detected to recheck the foreground region whose color is same as the background, and the background region whose color is same as the foreground. Let R_5 be the region whose color is same as the background and is inside the foreground, and R_6 be the region whose color is same as the background and is on the surface of the foreground (Fig. 4(d)). In other words, R_5 and R_6 are the foreground region whose colors are same as the background. The boundary of R_6 region contacts with the boundary of the background region. It is difficult to distinguish R_6 from the background by the ordinary chromakey techniques.

Therefore, to detect R_5 and R_6, the adjacency conditions with R_3 are utilized (Fig. 6).

The difference between $R_{1,2}$ and R_5 is whether it contacts with R_3 or not, while the color of $R_{1,2}$ and R_5 is same. This is because there exists no two-tone striped region whose colors are same as the background inside the foreground objects. Therefore, the regions that do not contact with R_3 among R_1 and R_2 can be judged as R_5.

The distinction is executed at each pixel in the case of R_1, R_2, R_3, and R_4. However, R_5 is searched at each conjunct region (Fig. 7(a)). Here, let $R_{i,j}$ be a subset of R_i. $\partial(R_{i,j})$ and $adj(R_{i,j})$ denote the boundary (the edge pixel) of $R_{i,j}$ and the adjacent region of $R_{i,j}$ which is a neighbor pixel of $\partial(R_{i,j})$ outside $R_{i,j}$, respectively (Fig. 7(b)). Then, R_5 is defined as follows:

$$\begin{aligned} R_5 = \{&R_{i,j}|R_{i,j}\subset(R_1\cup R_2), \\ &\forall(u,v)\in R_{i,j}(adj(R_{i,j})\notin R_3)\}. \end{aligned} \quad (8)$$

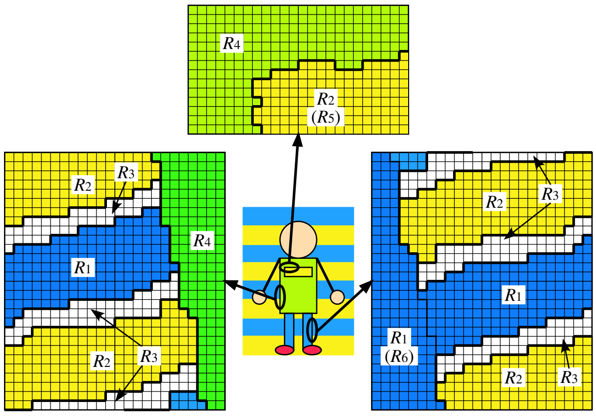


Fig. 6 Boundary detection of foreground. Top image: foreground region whose color is same as the background and that is inside the foreground (R_5). Left image: ordinary foreground region whose color is not same as the background (R_4). Right image: foreground region whose color is same as the background and that is on the surface of the foreground (R_6).

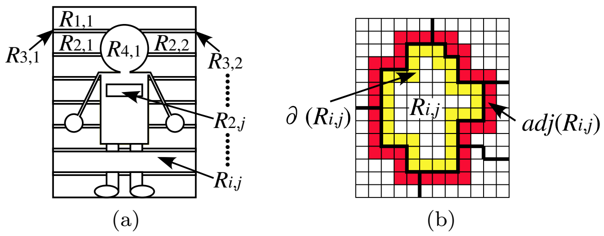


Fig. 7 Conjunct region. (a) $R_{i,j}$. (b) $\partial(R_{i,j})$ and $adj(R_{i,j})$.

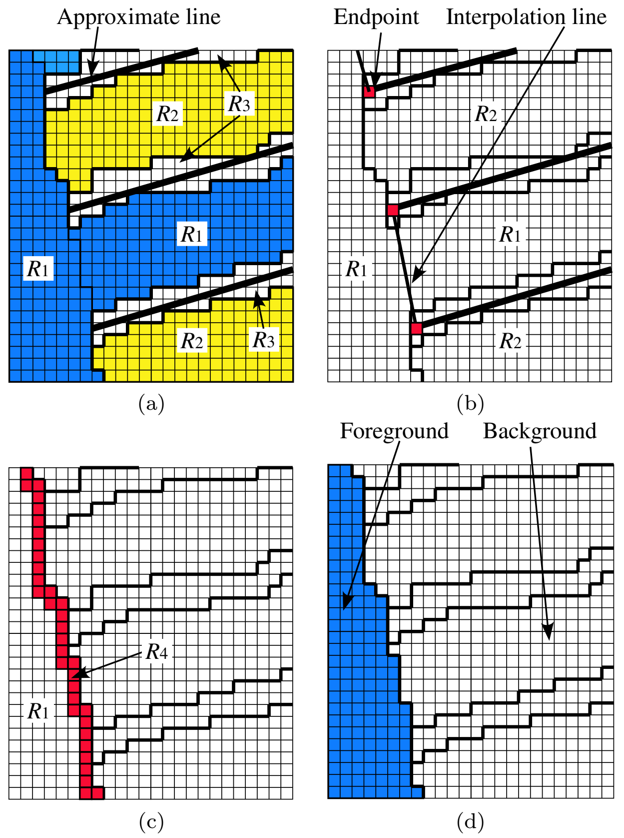


Fig. 8 Detection of R_6 region. (a) Approximate lines of R_3. (b) Endpoints of R_3 and interpolation lines between two endpoints of R_3. (c) Boundary of R_6. (d) Extraction of foregrounds.

To determine R_6 region, endpoints of R_3 are utilized. R_3 regions become horizontal lines if the stripes and the scanlines of the camera are perfectly horizontal. However, this does not always occur. Therefore, the approximate line of each $R_{3,j}$ region is calculated (Fig. 8(a)). After that, the endpoints of the approximate lines are detected (Fig. 8(b)). The neighbor areas of the endpoints that are adjacent to R_6 have same color as C_1 or C_2 (Fig. 8(b)), although the foreground next to the endpoints has different color from C_1 or C_2 (Fig. 9(a)). After judging the endpoints next to R_1 or R_2, these points are connected smoothly with interpolation lines (Fig. 8(b)). To detect the boundary of R_6, each pixel which is on the interpolation line is regarded as R_4 (Fig. 8(c)). As the result of these procedure, the region that is surrounded by the interpolation lines and R_4 becomes the same region as R_5 which do not contact with R_3. Therefore, R_6 can be obtained by the same way of detecting R_5 (Fig. 8(c)).

$$R_6 = \{R_{i,j} | R_{i,j} \not\subset R_5, R_{i,j} \subset (R_1 \cup R_2), \forall(u,v) \in R_{i,j}(adj(R_{i,j}) \notin R_3)\}. \tag{9}$$

On the other hand, the endpoints of the approximate lines of $R_{3,j}$ regions that contact with the foreground regions whose colors are not same as the background colors can be judged easily. These endpoints are not in contact with R_1 and R_2 regions in the direction of approximate lines of $R_{3,j}$ regions when the adjacent conditions are searched along the approximate lines (Fig. 9(a)). Therefore, these endpoints are not connected with interpolation lines, and the boundaries of R_4 remain precisely (Fig. 9(b)).

In this way, the distinction between R_4 region and R_6 region can be easily executed.

After that, the image is divided into six regions (Fig. 4(d)) and the extraction procedure finishes. Accordingly, the foreground region of the image R_{fg} is obtained as follows (Fig. 4(e)):

$$R_{fg} = \{(u,v) | (u,v) \in (R_4 \cup R_5 \cup R_6)\}, \tag{10}$$

2.4 Image Composition

The extracted foreground and another background are combined. The process that smoothes the color of the foreground's boundary against the new background is carried out to create natural images. The human operator decide the position and the size of the foreground objects in compliance with the new background that the relationship between objects do not become unnatural (Fig. 4(f)).

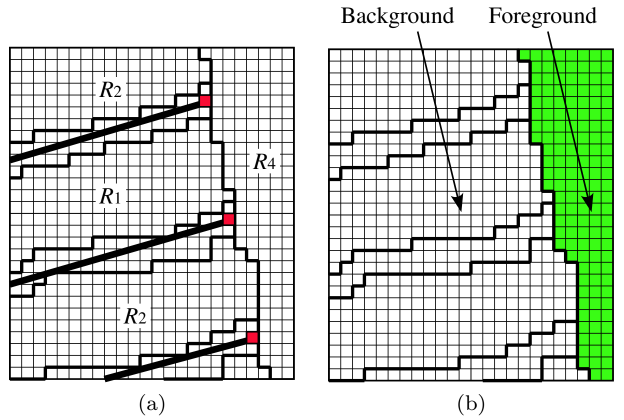


Fig. 9 Detection of foreground regions whose colors are not same with background colors. (a) Endpoints of R_3. (b) Extraction of foregrounds.

3. Experiments

Experiments were done in the indoor environment. In our experiment, horizontal stripes were adopted to extract the boundary precisely because human object is vertically long. The colors of the background were set blue and yellow from the trial and error results that blue is the complementary color of the fresh color, red is similar with the color of brown hairs, and so on. The background was made of blue and yellow papers that are commonly sold in the stationery. The width of the stripe was set as 35mm to interpolate the boundary of R_6 region precisely.

We used two digital cameras in experiments to verify the influence of the camera's individual difference. When the resolution of the image was 640 × 480 pixel, the size of the mask of a median filter for noise removal was set as 3 × 3. l (the length of R_3 region) was set as 3, and s_{max} (the threshold value for isolated point removal) was set as 4.

In Fig. 10, a sheet of blue paper that is same paper as the background is rolled around the left arm of the foreground person and a sheet of yellow paper is put on his shirt to examine the case of the same color clothes (Fig. 10(a)). The result of the background color extraction and the detection of the endpoints of R_3 are shown in Fig. 10(b) and (c), respectively. The extracted foreground is shown in Fig. 10(d). This result shows that the foreground regions whose colors are same with the background are extracted without fail. The result of the image composition of the extracted foreground and another background is shown in Fig. 10(e).

This method has been verified with a lot of people whose clothes were different in an indoor environment where the lighting condition changes as time goes on. Fig. 11 shows an example of these experimental results. The background image (Fig. 11(a)) and the foreground image (Fig. 11(b)) can be merged with our proposed

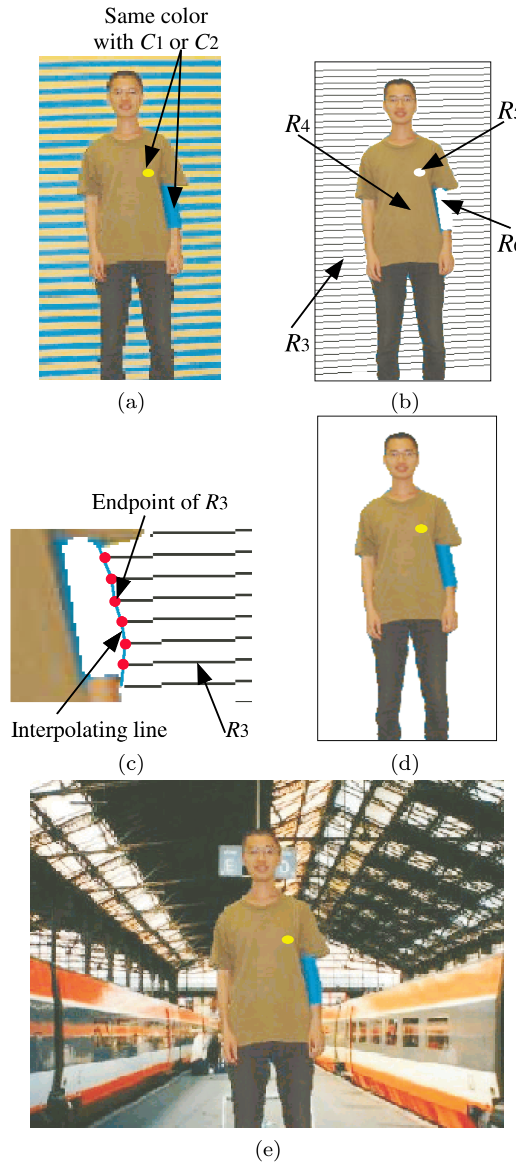
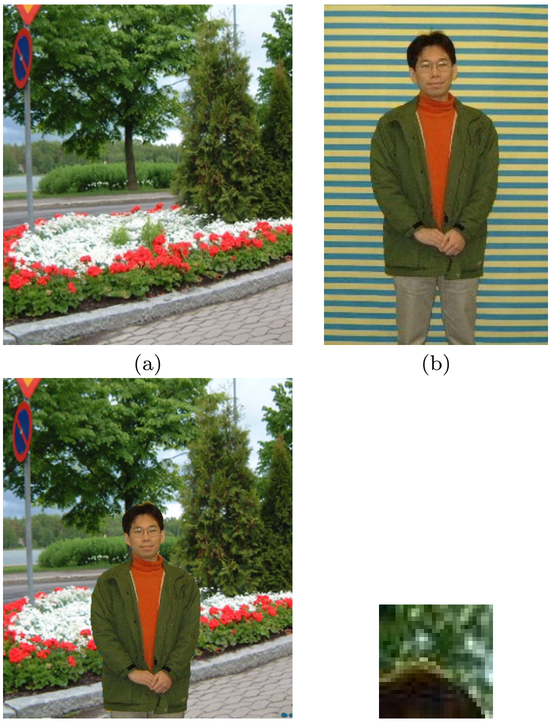


Fig. 10 Result of region extraction II. (a) Original image. (b) Background color extraction. (c) Detection of R_6. (d) Foreground extraction. (e) Image composition.

chromakey technique, and the image composition is realized (Fig. 11(c)). The enlarged image of the foreground person's hair is shown in Fig. 11(d). From this result, it is shown that the detail of the boundary of the foreground object can be detected with our method.

In almost all cases, R_3 region was able to be extracted, because our extraction algorithm of R_3 is hardly influenced by the color distortion and the color blur. The accuracy of foreground object extraction did not change when the camera changed in the case of same foreground objects. Therefore, the robustness of our method was verified.

The total computation time for the foreground extraction and the image compositing is about 0.75s on Windows 2000 with one PC/AT computer (CPU: Pen-



(a) (b) (c) (d)

Fig. 11 Result of region extraction I. (a) Background image. (b) Foreground image. (c) Image composition. (d) Enlarged image.

tium III 996MHz, Memory: 256MB) on the average. The time beyond 2/3 of total computation time is spent on the noise removal (the median filter and the removal of the isolated areas). It means that the algorithm of the region extraction is very simple. Therefore, the computation time can be reduced when the computer with a high efficient CUP and DSP board is used.

As the examples of failure, it occurred occasionally that the shirt of thin yellow looked the same as the color of the background yellow when the flash of the camera was used. Foreground extraction sometimes went wrong when foreground objects' colors were perfectly same as the background and these sizes were very large.

Although extraction error occurred infrequently because some threshold values were not adjusted for the lighting condition, our method could work successfully with large proportion of cases. From experimental results, the effectiveness of our proposed method has been verified.

4. Conclusions

In this paper, we propose a new region extraction method with a chromakey technique using two-tone striped backgrounds. We utilize the adjacency condition between two-tone striped areas on the background, and extract the foreground regions whose colors are same with the background. Experimental results show that the foreground region is constantly extracted from the background despite of the colors of the foreground objects.

Although our proposed method can work successfully, several problems still remain.

As the future work, the thresholding process of the background colors must be executed more precisely, because exact estimation of alpha value around the boundaries between the foreground and the background is not executed in this paper. We can estimate alpha value around the boundaries between the background and the foreground whose color is not same as the background by using the previous works that can estimate alpha value exactly, e.g. [13], [14]. As to the boundaries between the background and the foreground whose color is same as the background, we cannot estimate alpha value by using above-mentioned approaches. Therefore, the shape of the foreground objects must be estimate at first, e.g. energy-minimizing spline interpolation by using the coordinate values of endpoints of R_3 regions, and then the alpha value is estimated.

We have to improve the processing speed to treat with moving picture in real-time by using the hardware with high efficiency as mentioned above.

The lighting condition must be considered when the lighting condition of the foreground image is different from that of the background image, e.g. [18].

The biggest problem is that our method fails the foreground extraction when actors wear two-tone striped clothes that have the same colors as background. In that case, the width of the background's stripes can be utilized for estimating whether it is the foreground or the background. The pattern and the size of the background must be also optimized to improve the reliability of the foreground extraction and the quality of the composed images, e.g. [19], [20].

Acknowledgement

This work was partly funded from Hoso-Bunka Foundation, Inc., Japan.

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