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The Development of a Eigenface Detection System

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Abstract: This research was developed with the purpose of detecting and recognizing the face at a high speed on real time and then applying the detection and the recognition to a security system. The algorithm that was developed through this research was designed, so that, the effective distinguishing of the face is possible in the low-resolution, video environment on real time. The face detection method is researched by verifying the final facial domain through the eye, mouth and facial contours information after exploring the position of the face by using the facial domain separation technique based on the dispersion. Regarding the real-time face detection, the researches on the technologies for recognizing the faces and the researches that can trace the facial domains on real time must take place at the same time. Especially, as the facial domain detection and recognition take place regarding the subject who is traced, the mathematical analysis techniques regarding the accurate distinguishing of the moving subject and the movement detection and tracing are needed. The effective distinguishing of the face by the algorithm that has been developed through this research takes place in the low-resolution, video environment. By detecting the face at a high speed and by distinguishing according to it, the application of the security system is possible right away. The main application field of this research is the living body recognition field. Among the living body recognitions, the facial recognition has been receiving the attention especially because it possesses the strong points with regard to the economy, the convenience, the convenience of the user, etc. As such a research result can be spread throughout the overall security and certification industries, researcher believe that the forecast for the development in the future is very bright.

Key words: Face detection, mathematical analysis techniques, security system, certification industries, Eigenface, development

INTRODUCTION

Recently, as a living body recognition technology, the face recognition technology of which the discrimination capability is excellent and of which the utility and the convenience are extraordinary has been carved in relief (Chellappa *et al*., 1995; Chen *et al*., 2001). Regarding the face recognition technologies, there are distinguished into the face detection technology and the recognition function. The face recognition is a system that recognizes a person by using the face that was detected. As a result, the face extraction technology is an indispensable, pretreatment technology for the recognitions of the face and the facial expression. Recently, independently, too it has been applied to the diverse fields including the video searches, traces, surveillances, etc. As the face images get extremely distorted by the facial expressions, the illumination, the changes of the time point, etc. and their big changes take place according to the style of the hair, the makeup, the glasses, etc., the perfect detection of the face domain from the background is a difficult problem. Also, regarding the photo images that were inputted through a digital camera, their backgrounds, their degrees of the brightness at the time of the taking and their distances to the face at the time of the taking are different from each other. And because of the slopingness of the face of figure who is the subject and the others of the like, there occur the cases in which their use in the searches right away is impossible. Although, the face detection technologies have been researched at the many research centers and universities by being interlocked with real-time face detections until now, a lot of problems have become exposed in terms of the real-time detection speed (Salvi *et al*., 2002; Elgammal and Davis, 2001). In this research by developing a high-speed face detection system, it intends to prepare a foundational technology that can apply it to the diverse fields including the face recognition and the searches, traces, surveillance, etc. within the videos.

The face detection technology can be classified into the technology that explores the position of the face by using the color information resulting from the changes of the face illumination and the technology that verifies the final face domain through the information on the eyes, the mouth and the facial contours (Fig. 1).

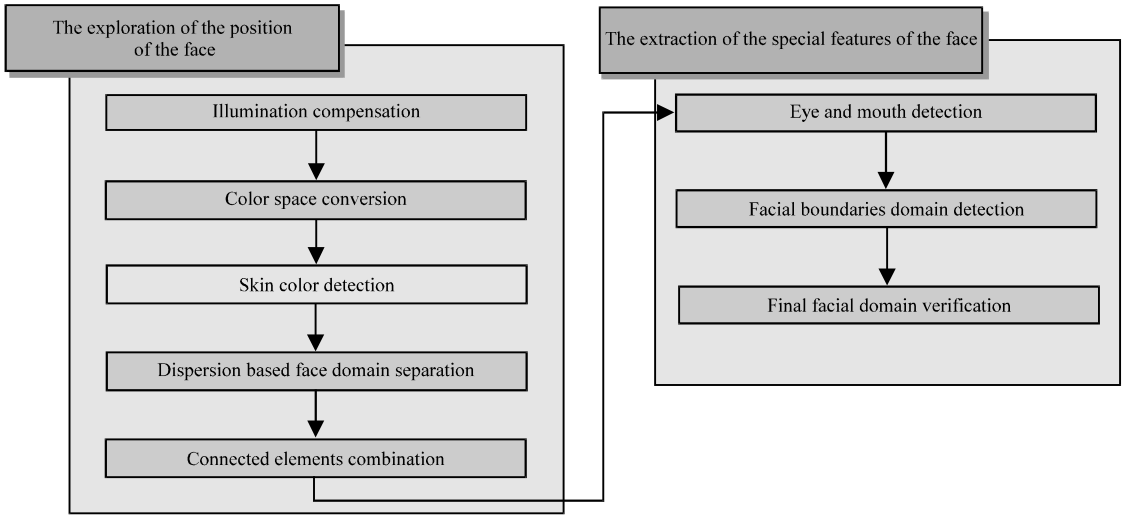

Fig. 1: The procedure of the face detection

MATERIALS AND METHODS

The high-speed face detection algorithm: Regarding the technologies used for the extraction of the face areas, there are the method based on the color of the skin, the Eigen function method (Etemad and Chellappa, 1996; Haritaoglu *et al*., 1999), the method using a nerve method, the method based on the special features, the method that combines the special features and the color of the skin, the method using the red-eye effect, etc. Among these, the method based on the color of the skin is not used solely and is mainly used in a form that has combined with a different method. Although, the Eigen function method shows a relatively high performance regarding the patterns of the special features, there is the weak point that, regarding the changes of the entire image like a change of the time point, the extraction performance is not guaranteed. Although, the method using the nerve network or the Support Vector Machine (SVM) shows the excellent performance in finding a face in a static image, it has a limitation in making the countless many object data, like the natural background, learned.

Regarding the real-time face detection, the researches on the technologies for recognizing the face and in addition, the researches for tracing the facial areas on real time are conducted at the same time. Especially, as the facial areas detection and recognition take place regarding the subject being traced, the technologies for the accurate distinguishing of the moving subjects, the detection of the movements and the tracing of the movements are needed.

The researches and developments regarding the detection and the tracing of the movements

The semiautomatic creation of background: The simplest and most general method for extracting the moving subjects is the background deletion method. The background deletion method is a method that obtains the movement area by deleting the image that was inputted in the background model that was prepared. In order to use this method, the background model is created by receiving the input of the inputted background image for between several seconds and several minutes as in Fig. 2. The background that was created in this way becomes different from the information of the background model because it becomes sensitive to the changes of the brightness of the inputted image according to the illumination of the surroundings, the special characteristics of the camera (Haritaoglu *et al*., 1999; Hwang *et al*., 2000; Moghaddam *et al*., 1996), the appearance or the disappearance of the pedestrian. In order to solve such a problem, the adaptive background subtraction method is used. As a method that continuously renews the background model, the initial background model of the adaptive background subtraction method becomes a background model that was created semi-automatically. And with the passing of time, it gets renewed according to the Eq. 1. Figure 2 shows the process of creating the background model semi-automatically:

$$B^{*}_{+1}(x) = \begin{cases} a.B^{*}(x)+(1-a) \\ B^{*}(x) \end{cases} \quad (1)$$

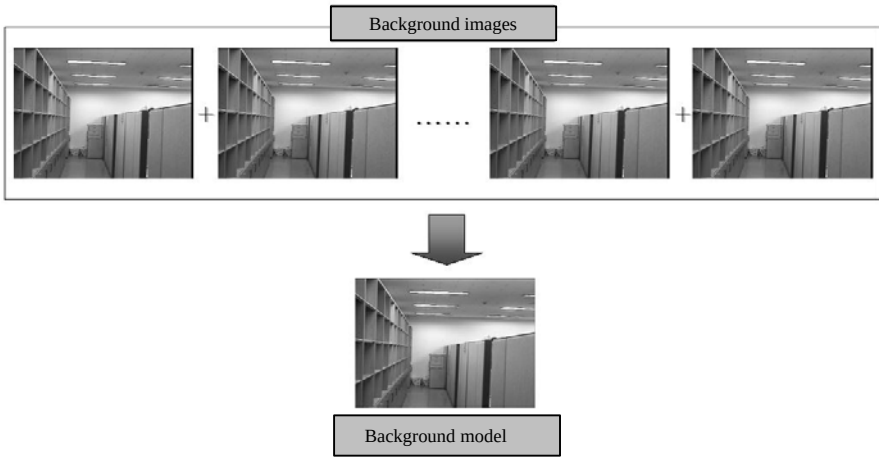

Fig. 2: The semi-automatic background modeling

The pixel that has a movement. The pixel that does not have a movement. Here, a represents the time-cycle of the input of an image.

The detection of a movement through the background model: In order to extract the moving subject, the background image is eliminated using the adaptive background subtraction method. The method of using the difference of the pixel values of the background and the image that was inputted was used. At this time, the problem is how much higher the value of the pixel value must be in order to become the criterion for classifying into a moving object. For this, the critical model Tn(x) of the initial difference of the pixel points was created. And, by renewing the critical value at each pixel point according to Eq. 2, like renewing the background model, it was made, so that, it adaptively changes according to the changes of the background model or the changes of the brightness of the surroundings. When one image has been inputted, Eq. 2 shows the process of detecting a movement area in the background image:

$$T_{+1}^{*}(x)=\begin{cases}a.T^{*}(x)+(1-a).\left(5\times\left|I^{*}(x)-B^{*}(x)\right|\right)\\T^{*}(x)\end{cases} \quad (2)$$

The development of a technique using the motion vector: Like the background subtraction method, the motion vector information is a method that is used a lot in order to detect the moving subjects. The pixel that has a movement.

In order to obtain the motion information, the frame difference method which mainly uses the difference between the images of the front and the back was used. Regarding the method of using 2 consecutive images, in the case in which the movement was small as the case in which the subject could not be found took place, the method of calculating the differences of the frames in the 3 consecutive images was used. Equation 3 shows the method of detecting the movements in 3 consecutive frames. Here, the $I_n^{(x)}$ represents the grey value at the pixel point x of the nth input image:

$$\left(\left|I_n(x)-I_{n-1}(x)\right|>T_n\right) \text{ and } \left(\left|I_n(x)-I_{n-2}(x)\right|>T_n\right) \quad (3)$$

The detection of the movement using the background model and the motion vector: In the system that detects the moving subject through the background subtraction method, either the object that is in the process of establishing a background model establishes the background model and disappears or in the case of the adaptive background subtraction method and in the case in which there is no fraction information, the object gets included in the background model. In this way, if the moving objects gets included in the background area (Fig. 3) in the area in which the object is included as seen in Fig. 3a, the problem of the movement always taking place occurs. Regarding the method of using the frame differences (Fig. 3b), only the movement area gets detected. Therefore, the problem of not being able to find the accurate form of the subject and only the contours being detected takes place.

In order to supplement the weak points of the adaptive background subtraction method and the motion vector method, the moving subject is detected by combining two methods. With the weak points of the background subtraction method which are the objects that do not have any movements and the errors, the two methods can eliminate the detections of the movements

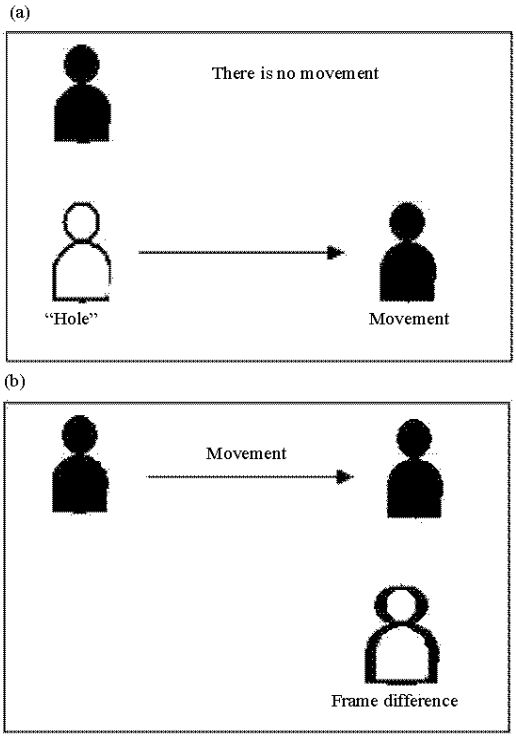

Fig. 3: a, b) The problems of the background subtraction method and the frame difference method

regarding the objects included in the background model. And by solving the problem of detecting only the contours of the moving subject which is a weak point of the frame difference method, the accurate area of the moving subject can be detected.

The research on the modeling of the shape of the face: It is only by detecting the facial areas that prove to be helpful to the facial recognition and consecutively handing over the recognition engine that the efficient rate of recognition gets represented. As such the detections using only the color of the skin get around to detecting the areas of the rotations of the face and the sides. But in the area that was obtained in this way, either the hand of a person or a different physical part gets included. So, the accurate face can be detected through a verification of the facial form, eye form and mouth form.

The facial detection method using the model measures the degree of similarity through an operation comparing the facial area that was detected and the template. And, according to the high degree of similarity, the area of the face and the process of the certification regarding the individual can be carried out. The basic principle regarding the template matching is as in Eq. 4:

$$s(x, y) = \sum_{y'=0}^{h-1} \sum_{x'=0}^{w-1} \left[T(x', y') - I(x+x', y+y') \right]^2 \quad (4)$$

Where:
S = The degree of similarity
T(x,y) = The template value
I(x, y) = The input image value

The detection method using the fixed template possesses the weak point of the degree of the accuracy markedly falling according to the size, the direction and the changes of the illumination of the facial area that was extracted. In order to overcome this in this research, the template is changed according to the situation and the comparison is carried out with the image that was extracted. This method heightens the degree of accuracy and maintains the accuracy of the extracted area. In the case of a change of the size, regarding the area that was extracted, the method of matching the existing templates by organizing the information of the pyramid templates with the diverse sizes is used. As the pyramid templates possess the information with the diverse sizes, the time of the calculation can be reduced.

Regarding the candidates of the special features of the face that were extracted, the images regarding the edges of the special features are obtained through the horizontal edge operations. Afterwards by using the variance projection function, the distributions of the histogram regarding the vertical and horizontal areas are obtained. And in these areas, through the analysis of the change values, the candidates of the information of the special features of the face are decided. In this case, compared to the method of calculating one dispersion, the efficient extraction of the special features is possible. The vertical and horizontal brightness can be represented as the following:

$$V(x) = \int_{y_1}^{y_2} I(x, y)dy$$
$$H(y) = \int_{x_1}^{x_2} I(x, y)dx \quad (5)$$

Each of the average values regarding the values of the vertical and horizontal brightness can be calculated as the following:

$$V_m(x) = \frac{1}{y_2 - y_1} \int_{y_1}^{y_2} I(x, y)dy$$
$$H_m(y) = \frac{1}{x_2 - x_1} \int_{x_1}^{x_2} I(x, y)dx \quad (6)$$

With the center of the candidate area as the standard, by using the difference of the intensity in the above

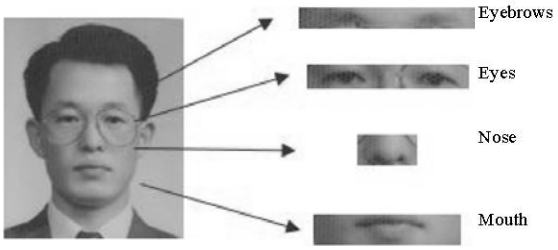

Fig. 4: The extraction of the special features of the face using the structural position information

area and the position information and through a comparison of the left and the right, the eye area is finally decided. Through a comparison of the intensity of the below part of the center of the candidate area, the mouth area can be detected (Fig. 4):

$$\sigma_v^2(x) = \frac{1}{y_2 - y_1} \sum_{y_i = y_i}^{y_2} \left[I(x, y_i) - V_m(x) \right]^2$$
$$\sigma_h^2(x) = \frac{1}{x_2 - x_1} \sum_{x_i = x_i}^{x_2} \left[I(x_i, y) - H_m(x) \right]^2 \quad (7)$$

Regarding the candidates of the special features of the face that were detected above, the positions of the special features of the face are understood through a comparison between the mutual, locational information and the previous position and the others of the like. The information that can be used the most preferentially is the eye area. The degree of the rotation of the face area that was detected by using the coordinates of the detections of the areas of the two eyes can be understood. And the face can be corrected by using this information. The reason why the correction is needed has an intimate relationship with the improvement of the rate of recognition of the face recognition engine. And it is necessary in order to realize a face detection method that is strong with regard to the movements and rotations too, of the subject of the certification in the certification system. At present, most of the face detection methods maintain the strength during the rotations of around 15~+15, too.

After acquiring the coordinate values that have the area of the left eye as x_1, y_1 and the area of the right eye as x_2, y_2 an image that is strong regarding the recognition is acquired by using the two coordinate values, detecting the slope thatwas rotated and correcting this. Equation 8 for calculating the rotation angles of the face using the coordinates of the two eyes is the following:

$$\theta = a\cos\left(\frac{y_2 - y_1}{x_2 - x_1} \right) \quad (8)$$

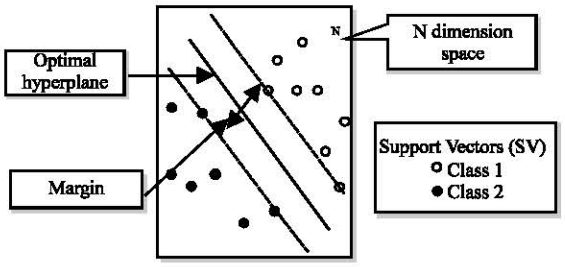

Fig. 5: The classification using the support vectors

By using the rotation angles obtained in this way, the process of handing over the facial area that was detected in the candidate area to the final recognition engine is carried out.

The development of the high-speed, facial image search technology: As the classification and recognition performances of the Support Vector Machine (SVM) are very extraordinary, it is a classification method that has been receiving the spotlight very much as a new recognition engine recently (Penev and Atick, 1996; Wiskott *et al*., 1997). Figure 5, this method is a very accurate recognition technology which nearly does not have any recognition errors as a mathematical approach method that organizes the optimal hyperplan by using the vectors of the decimals that possess the most representative, special characteristics with regard to the classification of two or more classes and classifies the classes based on this. Especially, other than the optimal classification performance of the recognition engine because the real-time study of the system is possible, it is very much appropriate for the practical purposes. By taking the bottom-up classification measure which classifies in phases after making the pairs again with only one class that is more similar after comparing the pairs of the two classes each, it has the efficient structure which makes one learn only the model of the class that was newly added without any correction of the previously-learned models when studying the additional data. As such it can be easily applied without any lowering of the speed to the large-capacity searches, too.

RESULTS AND DISCUSSION

The development of an integrated, facial image recognition system: The organization of the entire system that has been integrated with the Digital Video Record (DVR) is as in Fig. 6. Here, as the DVR can use the maximum of 4 channels per one board, it is organized with the 4 channels. And by adding a board, the storage is possible up to the maximum of 16 channels at the same

Fig. 6: The integrated interface of the face detection system

time. In this research, up to 4 channels were used. The real-time video that was inputted in each and every channel was shown on the screen. And regarding each and every channel, the face detection function was added. Also by adding the real-time user registration function and the face recognition function, a system in which the real-time facial detections, registrations and recognitions are integrated in the DVR environment was developed. Figure 6 shows the general organization of the system that was developed.

CONCLUSION

The main application field of this research is the living body recognition field. Among the living body recognitions, the face recognition has been vigorously researched at present because it possesses the strong points, including the economy, the convenience, the user convenience, etc. By adding the living body certification function to the DVR system which had been substituting for the previous CCTV, it was able to see the performance and the possibility of the development. By integrating the high-speed face detection function with the DVR system, it can be applied as a surveillance tool with the new concept at the public places and the access-controlled areas where the unspecified many must surveilled through a non-contact method. Recently, the domain of the utilization has been getting bigger as a security access control system for apartments, houses, general residential areas, companies, public offices, etc.

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