Multi-Face Detection on static image using Principle Component Analysis

Hyun-Chul Choi*, and Se-Young Oh**

*,**Department of Electronic and Electrical Engineering, POhang university of Science and TECHnology (POSTECH), Pohang, Korea
*(Tel : +82-54-279-2880, E-mail: dreaming@postech.ac.kr)
**(Tel : +82-54-279-2214, E-mail: syoh@postech.ac.kr)

Abstract: For face recognition system, a face detector which can find exact face region from complex image is needed. Many face detection algorithms have been developed under the assumption that background of the source image is quite simple – this means that face region occupy more than a quarter of the area of the source image or the background is one-colored. Color-based face detection is fast but can't be applicable to the images of which the background color is similar to face color. And the algorithm using neural network needs so many non-face data for training and doesn't guarantee general performance. In this paper, A multi-scale, multi-face detection algorithm using PCA is suggested. This algorithm can find most multi-scaled faces contained in static images with small number of training data in reasonable time.

Keywords: face detection, principle component analysis, multi-scaled face, eigen-face

1. INTRODUCTION

As the society being informationized, maintenance of security becomes a very important issue and also people give heavy importance to recognizing system. Among many person recognizing systems, recently, research for face recognition system has activated because of its simplicity of hardware which consist of several camera and a computer. Detection of facial region should be preceded to do next-step recognition. Many face detection algorithms are proposed so far and they can be categorized as follows.

1) Color-based method [7], [8] : using skin color and some segmentation algorithms
2) Template matching method [6] : using facial feature(eyes, lip, nose, etc.,) texture or geometrical templates such as wavelets and facial symmetry
3) Genetic Algorithm [3] : updating parameters of shape template using Genetic Algorithm under some fitting criterion
4) Neural Networks [4], [5] : training neural networks to classify facial region form non-facial region.
5) eigen-face [1], [2] : extracting eigen-faces from several face images, and comparing source image and the image projected onto eigen-facial space.

Method 1) cannot applied to gray images and when the background color is very similar to the face color. Method 2) can be a robust detection method satisfying low detecting time and relatively high detection rate. But this can be trapped in local-feature-like region such as eye-like region. And this method can not guarantee general performance. Method 3) needs good criterion to fit the parameters of face shape models. And neural networks 4) needs a lot of training data and should be refined by repeated training. Eigen-face method 5) use entire face texture and shape for detecting face region. So detecting speed is low, but accuracy is high.

In this paper, we propose the method that, by using PCA (Principle Component Analysis), can detect most faces in static images which is obtained under not-much variant lighting condition. And this method also use multi-scaled search so as to detect multi-scaled face region within reasonable time.

This paper introduce how to make eigen-faces using PCA in chapter 2. In chapter 3, multi-scaled searching method is dealt to find various sized face candidates. Chapter 4 explains exact facial region from the candidates. Chapter 5 shows experimental results, finally chapter 6 make conclusion about this algorithm.

2. PCA – MAKING EIGEN-FACE SPACE

Eigen-facial space is the space which can be spaned by orthogonal eigein-faces obtained by principle components analysis. PCA can be applied to detect facial region by measuring distance between source image and its eigen-facial space projected image. [2] This measurement indicates how the image is like face because projection of non-facial image onto the eigen-facial space is facial like image. [1] To make eigen-facial space, PCA should be done on the training images. Fig. 1 shows how to make eigein-faces using PCA.

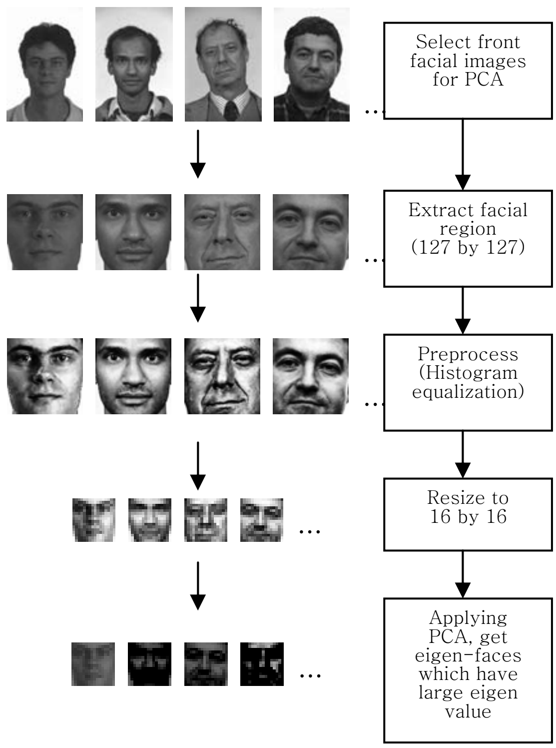


Fig. 1 Making eigen-faces using PCA

To make eigen-faces, pure face images should be manually extracted and preprocessed by histogram equalization. Then, resize to 16 by 16 pixel which is used as the size of searching window. Then, PCA is applied to the extracted face images to get principle components called eigen-faces which have largest eigen value. [2]

As the number of training images increases, the eigen-faces can span more general facial space. But experimental results show that 30's images are enough to satisfy general performance under invariant lighting condition.

3. MULTI-SCALED FACE SEARCHING

3.1 Multi-facial candidate detection with rescaling

In any picture, face detection system don't know how the size of faces is in the picture until the picture is fully searched. To detect face region exactly, calculating the sizes of face regions should be done at the same time. So the resizing & window sliding method of H. Rowley, et al. [5] is adapted to be fitted to the detection algorithm using eigen-facial space.

Multi-scaled face detection algorithm is shown in Fig. 2.

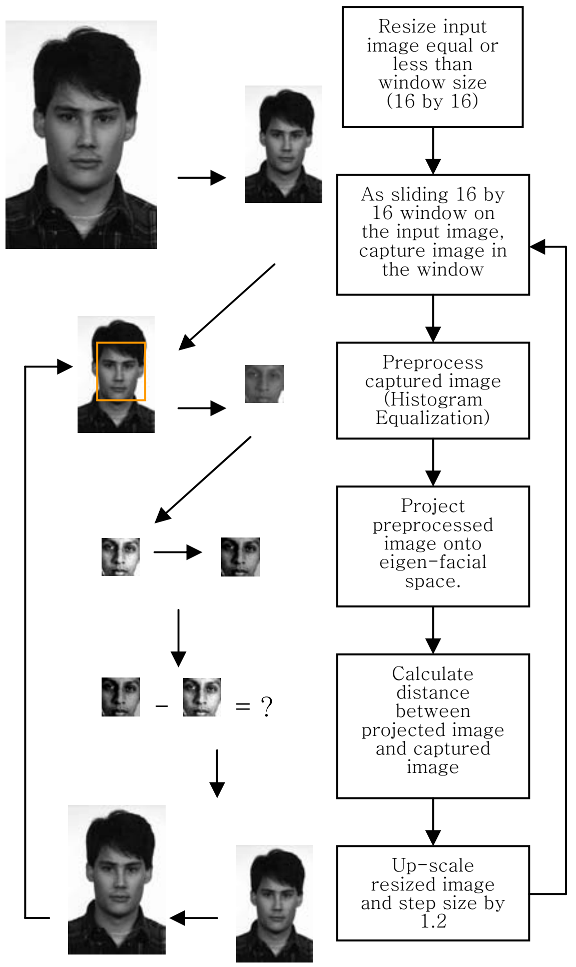


Fig. 2 Multi-scaled face detection algorithm using PCA

At first, after converted to 256-gray image, input image which contains one or several faces of various size should be resized to the size of sliding window. Here, 16 by 16 rectangular window is used. Resizing can be done by bilinear or bicubic resizing method to prevent image distortion.

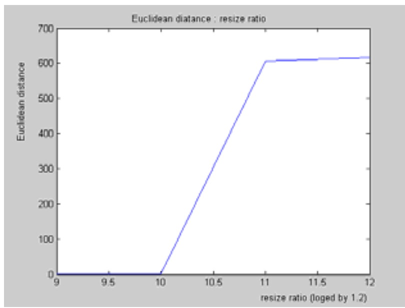
After resizing, window slides on the resized input image from the left-up position to right-down position with predefined starting step size, 2 pixel for both directions, horizontal and vertical. As the window sliding, the image in the window is projected onto the eigen-facial space and compared with its original image. Comparing is done by calculating Euclidean distance between the two image as vectors. This Euclidean distance indicates how the image in the sliding window is similar to face image. As the distance small, the image is more like face.

So far, the Euclidean distance map for specific scale can be obtained. After one cycle, these steps are repeated after enlarging the resized image and step size by scaling factor 1.2. Here, instead of enlarge the resized small image, resize input image to previous image size multiplied by scale factor to prevent low resolution problem.

Scaling, window sliding and calculating Euclidean distance are continued until the ratio of window size to the size of that scaled image reach predefined minimum value. This value indicates the minimum size of faces which are needed to be detected. In addition, the maximum size of faces can be defined and applied to the first resizing step. Then, only the faces of which size is within the predefined rage are detected.

3.2 One face detection case

In the case of only one face detection, searching all scale is not needed. If a possible facial region was detected while multi-scaled searching, then searching should be stop for saving detection time. To do this, detection system has to check the minimum Euclidean distance of each scale so as to find local minimum scale which has local minimum value of Euclidean distance. Fig. 3 shows minimum Euclidean distance via scale.



(scale = 1/1.2^resize ratio)

Fig. 3 Minimum Euclidean distance via scale

As up-scaling being continued with the ratio from 12 to 9, minimum Euclidean distance gets first local minimum value at the scale of 10. In this situation, detection should stop searching and detect the position, which has minimum Euclidean distance at the scale of 10, as the facial region.

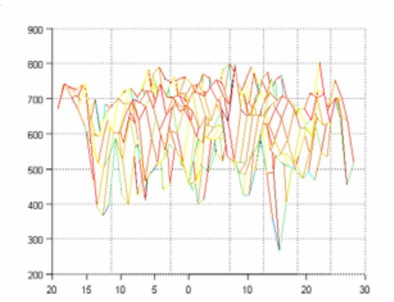
4. REFINEMENT OF FACIAL REGION

From the multi-scaled searching in chapter 3, the Euclidean distance maps of each scale are obtained. As an example, Fig. 4 shows one input image and its Euclidean distance maps. From these maps, it is true that real facial region has much lower distance value than those of other regions when the scale is fit to the facial region. However, several scales around the fittest scale also have distance values near the local minimum. Therefore, proper threshold and local minimum detection should be done to select face candidates from these local minimums.

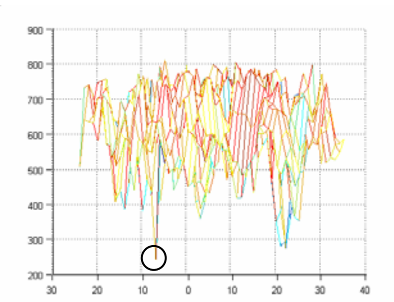
$$\begin{aligned} &if\ |ED(i,j,scale(l)) - ED(i,j,scale(l\pm1))| > threshold_2, \\ &\quad or\ ED(i,j,scale(l)) < threshold_1, \\ &then\ (i,j,scale(l)) = face\,candidate. \end{aligned}$$

Threshold can be decided experimentally, usually Euclidean distance bellow 250, and local minimum can be detected by measuring difference of Euclidean distances via position and scale. In Fig. 4, circles of (c), (e) indicate real facial region because they are local minima via scale and position in addition to being low then threshold 250. Around that those scale and position, candidates can be selected.

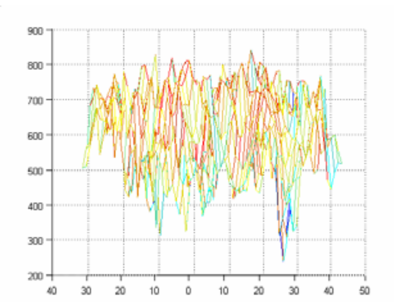
(a) A picture with faces (640 by 480)



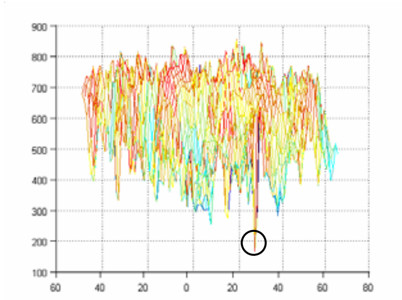
(b) starting scale = 1/1.2^14



(c) scale = 1/1.2^13



(d) scale = 1/1.2^11



(e) scale = 1/1.2^9

Fig. 4 Euclidean distance map of each scale

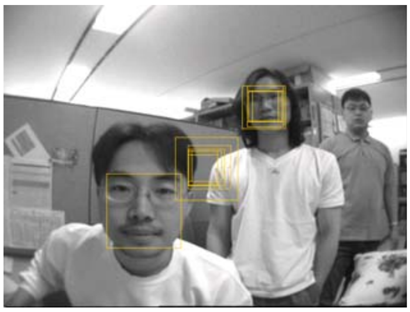
Using these all facial region candidates, exact facial region can be calculated as weighted sum of the positions of these candidates.

$$c = \frac{\sum_j (w_j \times cc_j)}{\sum_j w_j}, \tag{1}$$

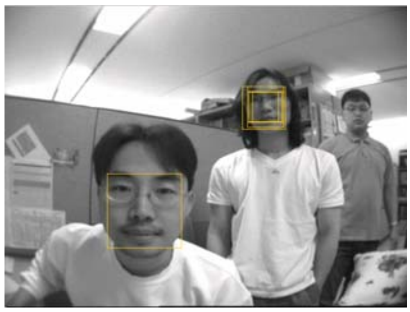
$$s = \frac{\sum_j w_j \times cs_j}{\sum_j w_j}. \tag{2}$$

w_j : *Inverse of minimum Euclidean distance of j-th candidate*

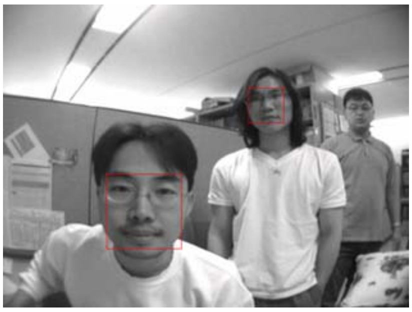
For given center of j-th face candidate (cc_j) and scale of j-th face candidate (cs_j), exact center (c) and scale (s) of face region can be calculated as (1), (2). Fig. 5 (a) shows the face candidates with ill-threshold. With ill-threshold, face-like background can appear as face candidate. Fig. 5 (b), candidates with proper threshold are located around real faces. The result of refinement is Fig. 5 (c).



(a) face candidates ill-threshold



(b) face candidates proper-threshold



(c) result of refinement

Fig. 5 face candidates and result of refinement

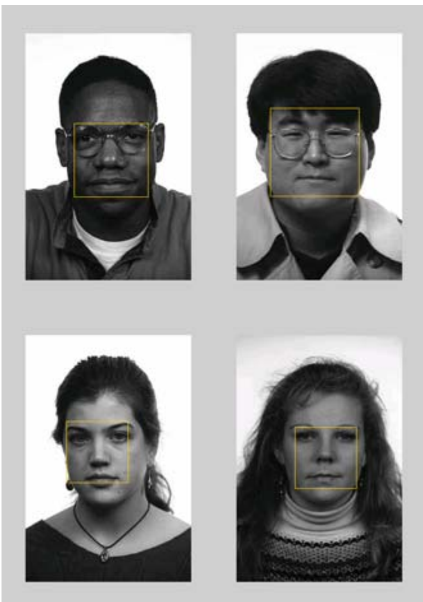
5. EXPERIMENTAL RESULTS

Pentium 4 3.0 GHz computer, one web camera with grabber board and MATLAB was used for experiments.

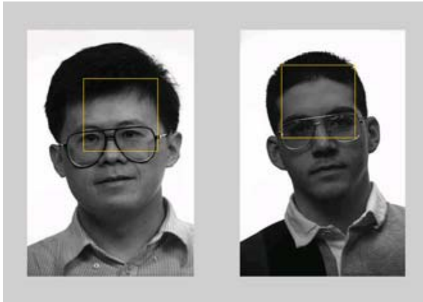
Multi-scaled searching algorithm was applied to 76 front faces of FERET DB. FERET DB contains images of various colored and races. The window size is 16 by 16, sliding step is 2 pixel for both of vertical and horizontal direction. Eigen-faces were made from arbitrary selected 34 faces among the 76 front faces. And 33 of the eigen-faces are used for detection. Table. 1 shows the performance of multi-scaled searching algorithm for FERET DB and Fig. 6 shows the result of detection. First row shows performance for trained images which is used to make eigen-faces, test images which is not used to make eigen-faces and total images. Performance for test images is 88% detection rate for test images. When all images were used for making eigen-faces, performance reached 97% detection rate. Detection time was less than 200 ms for full scale range searching, 90 ms for limited scaled range searching which stop when the local minimum appears.

Table. 1 Performance of multi-scaled searching, FERET DB

# of images for training	Trained	Test	Total
34	32/34(94%)	37/42(88%)	69/76(91%)
76	74/76(97%)	-	74/76(97%)



(a) well detected faces

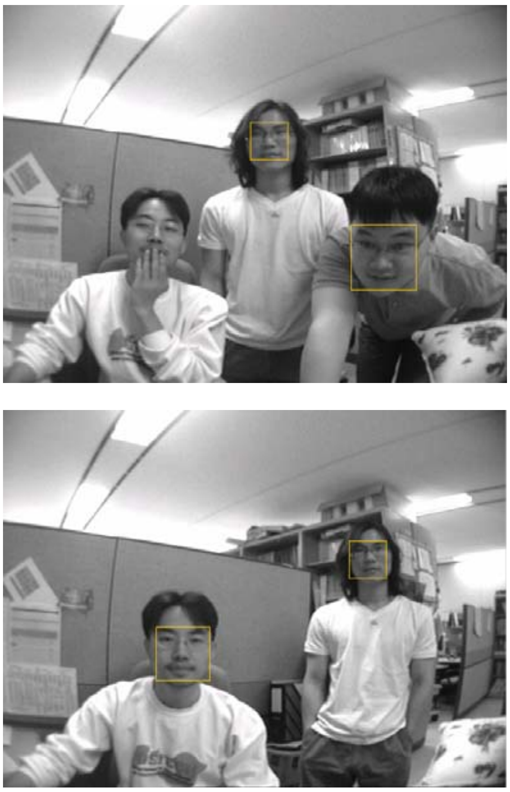


(b) ill detected faces

Fig. 6 Result of face detection, FERET DB

This multi-face detection algorithm was applied to the pictures which were obtained from Intelligent Robotics laboratory (IRLAB) in POSTECH. These pictures are lighting invariant, have three or less upright faces. And the size of them is 640 by 480. Eigen-faces were made by 7 face images of one person in the pictures and 6 eigen-faces were used for detection. Proposed method found exact face regions which occupy 1/9 ~ 1/144 of the whole image area in several pictures within 30 second. (see Fig. 7) After the size of face region was limited smaller range, less time consumption was achieved. And by increasing window sliding step at the price of accuracy, much less time consumption was achieved.

Suggested algorithm occasionally failed when applied to the pictures taken in different lighting conditions from that of the training faces. However this defect can be reduced by adding various lighting conditioned face image to training data for making eigen-faces. Lastly, this face detection algorithm is not rotation invariant. This can cover only 10 degree rotational variation from vertical arrangement because the faces used for training are vertically arranged.



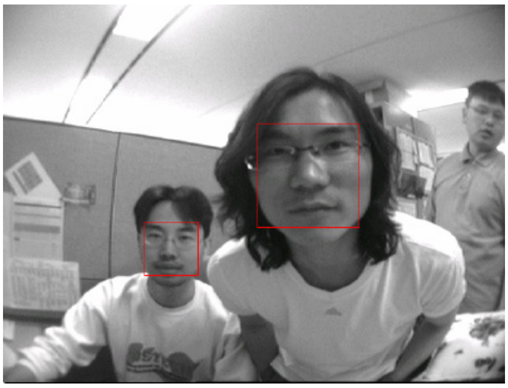


Fig. 7 Result of face detection, IRLAB in POSTECH

6. CONCLUSION

In this paper, Multi-scale, multi-face detection algorithm using PCA is suggested. This algorithm can exactly find vertical face region on static pictures within reasonable time. And the range of the size of detecting face can be limited as need. For rotation invariant and lighting invariant system, finding rotational arrangement of face using neural network or other methods and reducing lighting invariance remain for future works.

REFERENCES

[1] K-A Kim, S-Y Oh and H-C Choi, "Facial Feature Extraction Using PCA and Wavelet Multi-resolution Images", *Proceedings of IEEE International Conference on Automatic Face and Gesture Recognition*, pp. 439-444, 2004

[2] L. Rujie, Y. Baozong, "Eigenspace-Based Human Face Detection", *Proceedings of International Conference on Signal Processing*, Vol. 2, pp. 1305-1308, 2000

[3] Yokoo Y., Hagiwara M., "Human Faces Detection Method using Genetic Algorithm", *Proceedings of IEEE International Conference on Evolutionary Computation*, pp. 113-118, 1996

[4] H. Rowley, S. Baluja and T. Kanade, "Rotation Invariant Neural Network-Based Face Detection", *Proceedings of IEEE International Conference on Computer Vision and Pattern Recognition*, pp. 38-44, 1998

[5] H. Rowley, S. Baluja and T. Kanade, "Neural Network-Based Face Detection", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 20, No. 1, pp. 23~38, 1998

[6] K-M Lam, "A Fast Approach for Detecting Human Faces In A Complex Background", *Proceedings of IEEE International Symposium on Circuits and Systems*, Vol. 4, pp. 85-88, 1998

[7] Hadid A., Pietikainen M. and Martinkauppi B., "Color-based Face Detection using Skin locus Model and Hierarchical Filtering", *Proceedings of International Conference on Pattern Recognition*, Vol. 4, pp. 196-200, 2002

[8] Srisuk S., Kurutach W., "A New Robust Face Detection in Color Images", *Proceedings of IEEE International Conference on Automatic Face and Gesture Recognition*, pp. 291-296, 2002