Human Face Detection and Recognition using Principle Component Analysis

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1. Introduction

Image recognition is a very difficult task for a computer because of complexity of a natural scene. In order to recognize various kinds of object from a natural scene, robust image processing techniques are required under variation in size, orientation, lighting condition and so on. Moreover, it is also necessary to combine several image processing. The high-level information processing technologies realizing a natural scene recognition is not developed at present.

On the other hand, a human brain can easily recognize complex images unconsciously. It seems that highly complex processing can be achieved by massively parallel behavior of a large number of neurons and hierarchical information processing architecture that integrates low-level image features extracted from an input into meaningful high-level image features over several stages.

2. A Concept of Multi-object Recognition System

For the purpose of developing a real-time/high-level recognition technology, we propose a multi-object recognition system composed of 3D custom stack of multi-functional chips (Fig. 1) which has been presented in the 21st century COE program of Hiroshima University [1]. The hierarchical and massively-parallel processing of human brain are achieved using multi-functional chips and local/global wireless interconnects among LSIs based on a pixel-parallel circuit architecture. Furthermore, we apply the eigenfaces method which is one of the major pattern recognition methods using principle component analysis(PCA) [2, 3] to the algorithm of our proposed system. The multi-object recognition system can composed of image sensor, image normalizer, objects detecter, objects recognizer and multi-object database(DB) chips. In this paper, we demonstrate human face detection and recognition by numerical simulation using the eigenfaces method.

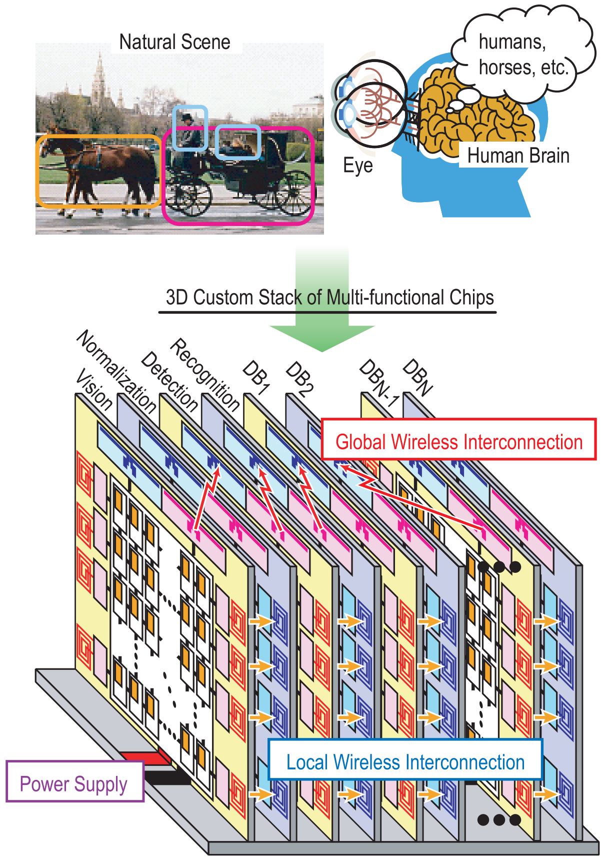

Figure 1: A concept of multi-object recognition system.

3. Calculating Eigenfaces with Principle Component Analysis

The eigenfaces method is based on the principal component analysis[2]. First, the face images in a dataset is decomposed into a small set of characteristic feature images, called eigenfaces, which are the orthogonal eigenvectors calculated from the face images. The eigenfaces are considered as the principal components of the original images. Next, a weight vector to represent face images as a linear combination of eigenvectors is calculated. Finally, by comparing the weight vector of an unknown new face to those of dataset's images, an unknown face can be identified as a person matched.

The generally procedure of the eigenfaces method is as follows: An i-th face image of a dataset composed of N images is represented as a vector $\mathbf{\Gamma}_i$ as shown in Fig. 2(a), where the number of pixels is M. The average face $\mathbf{\Psi}$ of all images is defined by $\mathbf{\Psi} = \frac{1}{N}\sum_{n=1}^{N}\mathbf{\Gamma}_n$. The preprocessed face $\mathbf{\Phi}_i$, which is subtracted the average face from each image, is defined by $\mathbf{\Phi}_i = \mathbf{\Gamma}_i - \mathbf{\Psi}$. As a result, the eigenfaces are calculated as eigenvectors $\boldsymbol{u}_k$ of the covariance matrix C of a dataset, $C = \frac{1}{M}\sum_{n=1}^{M}\mathbf{\Phi}_n\mathbf{\Phi}_n^t = AA^t$, where $A = [\mathbf{\Phi}_1\ \mathbf{\Phi}_2 \ldots\ \mathbf{\Phi}_M]$, A^t is a transposed matrix. Figure 2(b) shows the examples of eigenfaces of human face images.

A new face image $\mathbf{\Gamma}_{new}$ is transformed into so-called "face space" ω_k for $k = 1, \ldots, m$ by a simple operation: $\omega_k = \boldsymbol{u}_k^t\mathbf{\Phi}_{new}$, where $\mathbf{\Phi}_{new}$ is a preprocessed image of new face defined by $\mathbf{\Phi}_{new} = \mathbf{\Gamma}_{new} - \mathbf{\Psi}$. The face space ω_k forms a vector $\mathbf{\Omega} = [\omega_1\ \omega_2\ \ldots\ \omega_m]$ that describes the contribution of each eigenface for face image. Therefore, the simplest method for determining which face images are identified with a new face is to find the minimum Euclidian distance $\varepsilon_i = \|\mathbf{\Omega} - \mathbf{\Omega}_i\|^2$, where $\mathbf{\Omega}_i$ is a face space of i-th face image of a dataset.

One can reconstruct a preprocessed image $\mathbf{\Phi}$ by us-

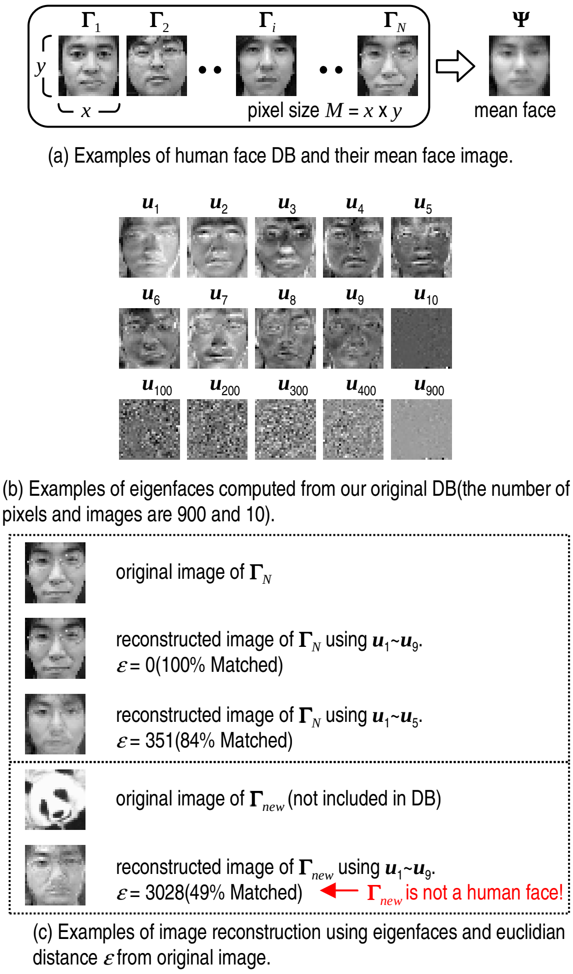

Figure 2: Face images and their eigenfaecs.

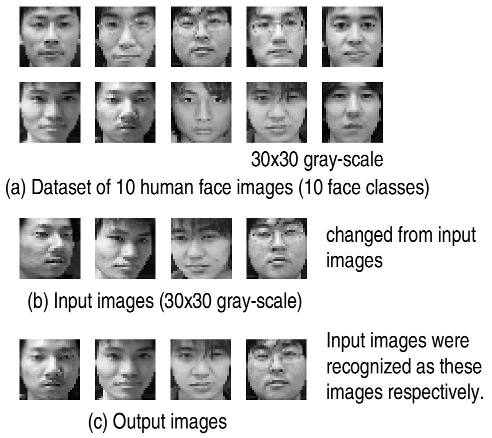

Figure 3: Numerical simulation results of human face recognition.

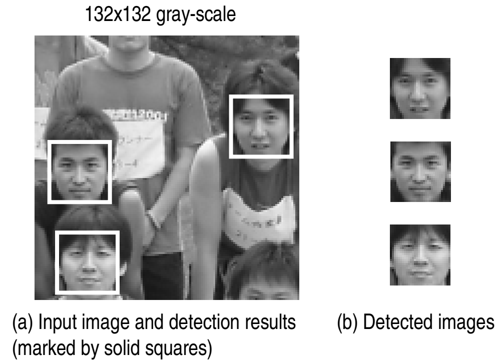

Figure 4: Numerical simulation results of human face detection.

ing its face space and the eigenvectors of a dataset as shown in Fig. 2(c): $\mathbf{\Phi}_r = \sum_{k=1}^{m} \omega_k \boldsymbol{u}_k$, $\mathbf{\Phi}_r$ represents a reconstructed image. If the Euclidian distance $\varepsilon = \|\mathbf{\Phi}_{new} - \mathbf{\Phi}_r\|^2$ is lower than a threshold, a new input image is classified as a human face.

4. Numerical Simulation Results of Human Face Detection and Recognition

We performed a numerical simulation of human face recognition by using the eigenfaces method. The face dataset composed of 10 persons is shown in Fig. 3(a). First, we calculated 9 eigenfaces and 10 face space from these faces, and then searched each minimum distance of face space between images of an input and those of an dataset according to 4 input images as shown in Fig. 3(b). As a result, input images were recognized as output images, respectively, as shown in Fig. 3(c). The human face recognition was performed accurately, even though there are some variations in face orientation. The total processing time was 0.13 ms with 3.06GHz Xeon Dual Processor. Therefore, the processing time per one person was about 10μs order by software.

Human face detection from a natural scene is shown in Fig. 4, where the eigenfaces of Fig. 3(a) were used for creating reconstructed face images. The simulation flow of face detection as follows: The input image as shown in Fig. 4 was raster scanned with a unite block of 30×30 regions. These scanned regions were reconstructed and their Euclidian distances were calculated. As a result, only three human faces were detected exactly as shown in Fig. 4(a) and (b). The total processing time was 4.6s, and the processing time per one scanned image was 0.2s.

The eigenfaces method has an effective performance to recognize and detect face image under being some variations and complexities.

5. Conclusion

We proposed a concept of the multi-object recognition system composed of 3D custom stack. We also confirmed human face detection in a natural scene and recognition under some variations using the eigenfaces method by numerical simulation. We are scheduled to extend the eigenfaces method to multi-object recognition and realize their VLSI implementation.

References

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