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Real Time Face Recognition Based on Face Descriptor and Its Application

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Abstract

This paper presents a real time face recognition based on face descriptor and its application for door locking. The face descriptor is represented by both local and global information. The local information, which is the dominant frequency content of sub-face, is extracted by zoned discrete cosine transforms (DCT). While the global information, which also is the dominant frequency content and shape information of the whole face, is extracted by DCT and by Hu-moment. Therefore, face descriptor has rich information about a face image which tends to provide good performance for real time face recognition. To decrease the dimensional size of face descriptor, the predictive linear discriminant analysis (PDLDA) is employed and the face classification is done by kNN. The experimental results show that the proposed real time face recognition provides good performances which indicated by 98.30%, 21.99%, and 1.8% of accuracy, FPR, and FNR respectively. In addition, it also needs short computational time (1 second).

Keyword: *face recognition, real time, LDA, face descriptor, face classification*

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1. Introduction

This paper presents an application of real time face recognition based on face descriptor for door locking system. The face descriptor is the dominant frequency content of sub-face (local) and whole face (global). The face descriptor is extracted by zoned DCT, non-zoned DCT, and Hu-moment. The main aim of DCT coefficients based face descriptor is to get rich information of face image which can give better achievement than that of compact features (CF) based method [1] for real time face recognition. The predictive linear discriminant analysis (PDLDA) is hired to drop-off the dimensional size of the descriptor and the k nearest neighborhood (kNN) is utilized for verification. The main aim of this work is to obtain strong face recognition against lighting variation which can be applied to the security system, i.e. door locking system which is an extended version of our previous work[2].

Face recognition has been widely developed by many researchers[3], such as statistical-based (ICA, PCA, and naive Bayesian), global features-based, artificial intelligent-based (i.e., genetic algorithm, artificial neural network, SVM and etc,) and any their variations-based [1, 2] face recognition algorithms. The most popular algorithm is face recognition based on subspace projection: LDA, eigenface (PCA), and their variations [4, 5]. The LDA and their variation become popular due to its simple implementation and less computation complexity. In addition, their discrimination power is higher than that of the PCA, which make the performance of LDA and their variation be better than PCA.

Discrete cosine transform (DCT) based face recognition [6] has been reported that it provided good performance compared to other approaches. Both PCA and LDA is possible to be directly executed on images in JPEG standard format unaccompanied by performing inverse DCT transform because they can work in DCT domain. The DCT-based system requires certain normalization techniques to overcome variations in facial geometry and illumination. However, both approaches extracted the face features using only block-based DCT. The face recognition method using selection DCT coefficients from 75% to 100% DCT and setting the high frequency to zero has been proposed to handle illumination problem[6]. However, it needs high computational time

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because inverse DCT transforms and Contrast Limited Adaptive Histogram Equalization (CLAHE) is mandatory to obtain an illumination invariant face image.

Regarding real time face recognition algorithms[7, 8], mostly the eigenface (PCA) has been successfully implemented. However, the PCA is lack of discriminant power, which make the system be lack of accuracy. In addition, the combination of compact features (CF) and LDA projection has been applied for real time face recognition[1]. The CF vector was extracted by LBP and zoned DCT, while the classification was performed by nearest neighbor rules. The LDA was employed for dimensional reduction of CF vector.

Therefore, alternative real time face recognition using DCT coefficients based face descriptor which consists of dominant frequency content extracted by discrete cosine transforms (DCT), local features extracted by zone DCT (block-based DCT) and shape information extracted by Hu-moment. The DCT coefficients based face descriptor tends to improve the performance of CF based face recognition because it has rich information.

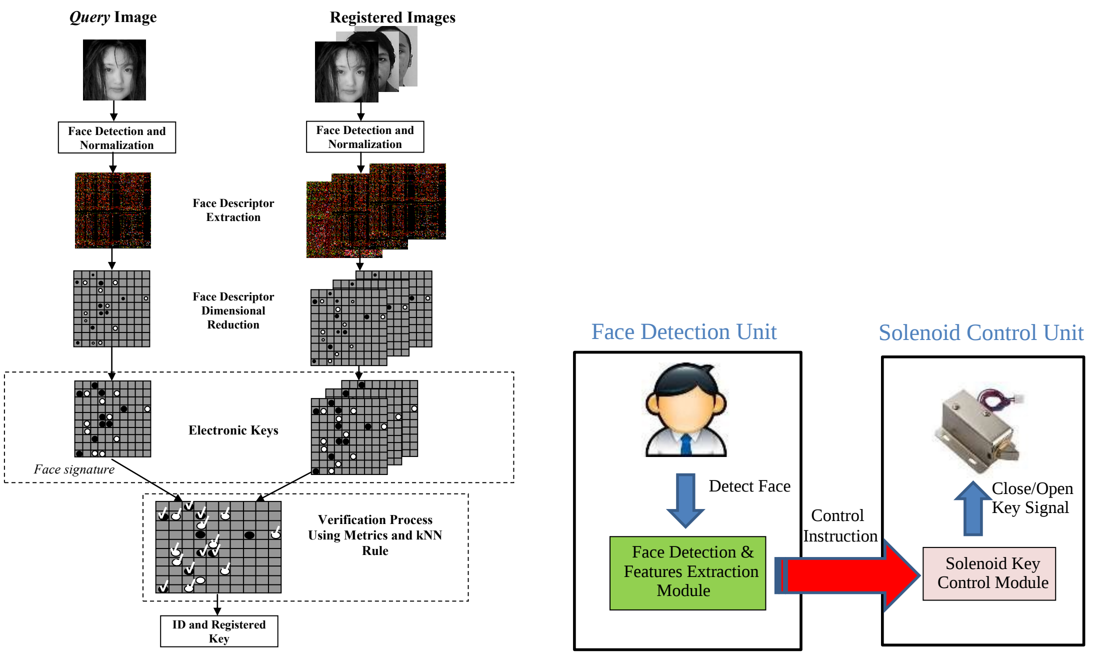
2. Proposed Method

In this research, there are two main modules: face recognition engine and its implementation for a door-locking system. The face recognition engine principally has three subsystems: face detection, feature extraction, recognition and verification rules, as shown in Fig. 1(a). While the door-locking system consists of a face recognition engine and solenoid control circuit, as presented in Fig. 1(b).

2.1. Proposed Face Recognition Engine

The mechanism of face recognition and verification can be described as follows:

1. Suppose, the training set is given to the recognition engine for finding out machine parameters and guiding the engine to be intelligent. Furthermore, face image descriptors that are



(a) (b)

Figure 1. Diagram blocks: (a) face recognition engine[2] and (b) door-locking based on face image.

extracted during the training process are stored in the database as registered face signatures. The face image descriptor is extracted by using a fast zoned and non-zoned DCT, and Hu-moment, then selected a small part of transformation coefficient having greatest magnitude. Then the chosen coefficients are quantized for sharpening the key features called as face signature.

2. In the recognition process, the query face signature is extracted by using a similar technique to the training process. Next, the similarity score is determined by matching query face signature and registered face signatures. In this case, the smallest score is concluded as the best likeness.

3. In the verification process, the kNN is hired to find the highest probability of query face signature, which is close to the registered face signature. If the probability of query face signature, which is close registered face signature of class B, the input query is verified as class A. The kNN is chosen because it could give good performance (91.5% of recognition rate and 2.66 seconds of computational time) for face recognition in small and compact devices(ARM processor)[9].

2.1.1. Face Acquisition

Face image acquisition is done by using a standard USB camera. Next, histogram equalization is utilized to decrease the effect of lighting condition during face acquisition. Finally, the Haar-like based face detection[10], which has been widely examined and provide robust performance among the others algorithm, is employed for face detection. Simply, the face detection algorithm starts from face localization to define a region of interest (ROI) of face, and then from the detected face ROI is confirmed by detecting the two eyes inside the ROI, finally the firmed face ROI is cropped and passed to face recognition engine for further process on real time face recognition. The illustration of face detection is presented in Fig. 2.

(a) (b) (c)

Figure 2. Face detection algorithms: (a) face localization, (b) eyes detection, (c) cropping face

2.1.2. Face Descriptor Extraction

In this paper, the face descriptor extraction process is shown by using diagram block in Fig. 3. The filtering and contrast stretching are also employed to eliminate the lighting variation effect during face capturing. In detail, the face descriptor extraction is done by using some steps as follows:

1. Performing the local binary pattern (LBP) and followed by performing none-zone DCT (on entire image) to obtain the global information of face image. LBP and its variation have been successfully implemented for face recognition[11]. In this case, small part (less than 64) coefficients are selected as global information. The LBP is implemented to get robust global information of face image against illuminations.

2. Performing zone DCT (as performed on JPEG compression) to obtain local features of the face image, as shown in Fig. 4. In this case, less than four coefficients are selected from

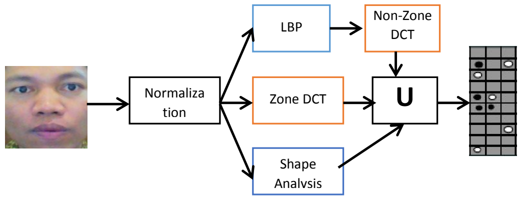


Figure 3. Face descriptor extraction processes

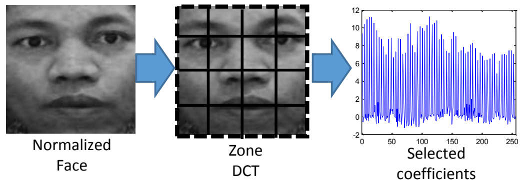


Figure 4. Local features extraction processes

each zone as local features. The local features represent specific information of sub face image which is available in some low frequency components.

3. Performing the shape analysis using Hu-moment to get shape information of face image. In this case, only four moments (first-fourth) is considered because the fifth-seventh moment's values are close to zero. It means that shape information is not available in the fifth-seventh moments.

4. Finally, combining the global information, local features, and shape information to get rich face descriptor.

In this work, the face descriptor is represented by the dominant frequency content of whole and sub face images. The local features represent the most information of key point. Similar to SIFT features, this face descriptor is rich of information which tends lighting invariant because the lighting variation has been decreased by filtering and contrast stretching.

2.1.3. Dimensional Reductions

In this paper, the predictive LDA (PDLDA[1]) algorithm is hired to drop-off face descriptor size. The PDLDA is similar to LDA which define optimum projection matrix, W, by eigen analysis of the between class scatter, S_b, and the with-in class scatter, S_w[1, 4]. The W has to satisfy the Eq. 1.

$$J_{LDA}(W) = \underset{W}{arg\,max} \frac{\mid W^T S_b W \mid}{\mid W^T S_w W \mid} \tag{1}$$

This algorithm has been established that can avoid the retraining problem of LDA. It can be done by redefining the S_b and the S_w using global mean, μ_a. It means the μ_a is estimated by calculating it from / sub-sample data that is randomly selected from a given data set.

Finally, the dimensional reduction is done by Eq. 2.

$$y_i^k = W^T x_i^k \tag{2}$$

where y_i^k is projected face descriptor and x_i^k is an input face descriptor. By using this concept, the input face descriptor can be decreased more than 50% of original size.

2.2. Door-Locking System

The door locking hardware system consists of five subsystems named: Raspberry module, a set of output power gain system, a server, a network switch, and a door solenoid system. The Raspberry module is used to control the door solenoid to locked or unlocked depending on the output status given by the software recognition system in the server. The server provides a logic condition 1 (refers to unlocked) or 0 (refers to locked). This logic condition wrote in a file which can be accessed through the network. A web server is installed on the server to provide this feature. A network switch is used to connect the server and the Raspberry through the computer network.

The Raspberry initial mode firstly sets to 0 which will lock the door solenoid. The Raspberry continuously checks the server output condition through the network. If the server status is different from the initial status, then the Raspberry processes the program to command the solenoid. The server status will drive the program to control solenoid either lock or unlock. The latest status, then used as the initial status, and the checking processes will continue.

The Raspberry uses servers logic output condition as an input and a Raspberry GPIO (general purpose input output) pin as an output. This Raspberry GPIO output status is used as an input by the door solenoid as a command to lock or unlock the door. Since the solenoid input voltage requirement is 12VDC and the Raspberry GPIO output voltage is 3.3VDC then a relay is needed to drive the solenoid. The relay has a minimum 5V input, which is higher than the Raspberry GPIO output (3.3V) as well as the current. To drives the relay, Raspberry will need a simple power gain system. A simple power gain system can be built using a transistor and some resistors as shown in the Fig 5.

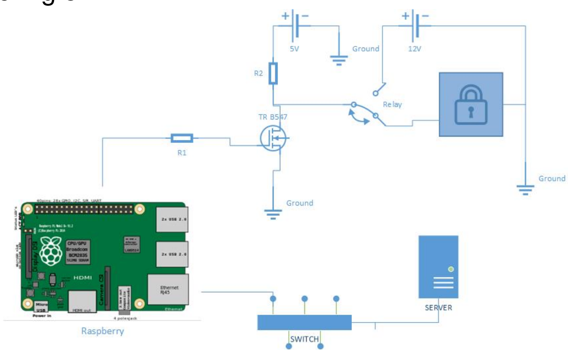


Figure 5. Circuits of door locking hardware system

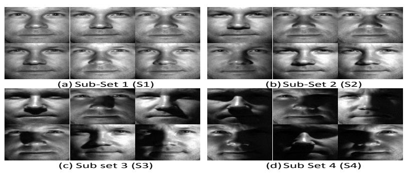
3. Experiments and Result Discussions

Both off-line and real time experiments were carried out to know the performance of face recognition engine based on face descriptor (FD). four well known face datasets: ORL[1, 12], Image Media Laboratory Kumamoto University (ITS) [1, 4], and India (IND)[4], and Yale B[13] were chosen for doing off-line experiments. The ORL dataset has 400 grayscale faces that were taken from 40 persons. Face variations example of the ORL dataset is presented in Fig. 6(a)[1]. ITS face database belongs to Image Media Laboratory Kumamoto University, which is an ethnic East Asia face image, especially Japan and Chinese. ITS has 90 samples and each sample has

(a) ORL dataset [12]

(b) ITS dataset[4]

(c) IND face dataset[2]

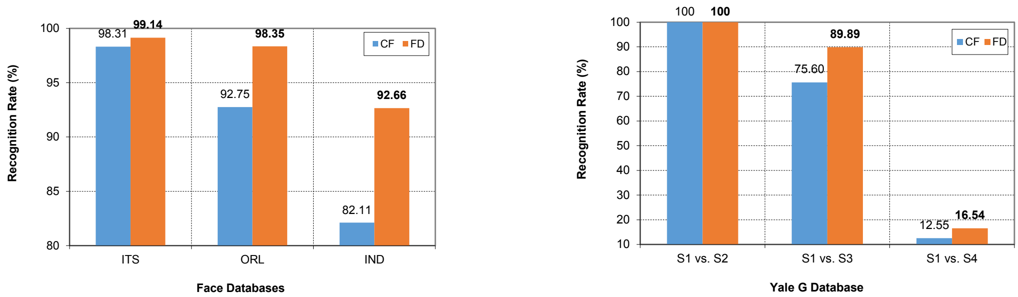


(d) Yale B[13]

Figure 6. The example of face variations of tested datasets.

10 to 15 face variations. Examples of face variations of the ITS face database can be presented in Fig. 6(b)[1]. Thirdly, India dataset is color face image dataset which has 61 persons (22 female and 39 male). Thee are eleven pose variations as presented in Fig. 6(c). Some facial emotions are also included in this dataset such as smile, disgust, neutral, and laugh[4]. The Yele B dataset is divided into four sets, as shown in Fig. 6(d). In this case, the sub-set 1 was chosen as training and the remaining sub-sets were selected as testing.

In addition, the off-line experiments were carried out by under conditions: firstly, 50% faces of each dataset were arbitrarily elected for training data and leftover part was chosen as querying images; secondly 10-Fold cross-validation was enforced for performance evaluation; finally, recognition rate and computational time were utilized as a performance indicator.



(a) On ORL, ITS, and IND datasets (b) Yale B dataset

Figure 7. Off-line performances of our face recognition compared to baseline (CF based method[1]) on tested datasets.

The experimental results (see Fig. 7) show that face recognition engine based on FD gives better performance than those baseline methods (compact features (CF) based face recognition[1]. In average, the FD based face recognition engine provides by about 96.72% of recognition rate on ORL, ITS, and IND datasets (see Fig. 7(a)). In other words, FD based face recognition engine can improve by about 5.66% the performance of CF based face recognition[1]. It can be achieved by our face descriptor that has rich information which is formed by global information, local features, and shape information. The global and local information is represented by some low frequency components of whole and sub-face images. This achievement is in line with the basic theory of signal processing that the most signal information is located in the low-frequency element.

In terms of robustness of FD to any variations of lighting condition compared with the CF method, the FD based method gives better performance than CF (see Fig. 7(b)). It proves that the FD has rich information which robust to lighting invariant due to filtering and contrast stretching before the extraction.

Regarding execution time, the FD based face recognition engine takes less than 1 second in average for performing the matching between querying face descriptor among the registered face descriptors of all tested datasets. It can be achieved because the face descriptor is represented by 32 elements of original size face images (128x128 pixels). From off-line experimental data, the proposed face recognition engine is potential to be used for electronic keys for door locking system.

In the real time experiments, the system was tested using large variability face images in terms of pose and capturing time. In this case, 1002 face images have been collected by using web camera Logitech C300 (1.3 MP (1280 x 1024)) from 13 persons of the staff on Informatics Engineering Dept., Engineering Faculty, Mataram University, in fifth days. From this dataset, 159 face images captured on the first day (almost 11 images for each person) were used as the training and 843 faces were prepared for testing. Examples of faces variation are shown in Fig. 8.

The parameters for real time evaluation of face recognition engine were accuracy, False Positive Rate (FPR), False Negative Rate (FNR), and computational time. The evaluation results affirm that the proposed face recognition engine using face descriptor has performed properly,

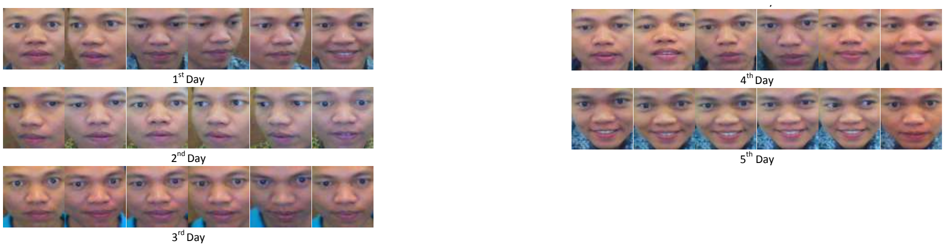
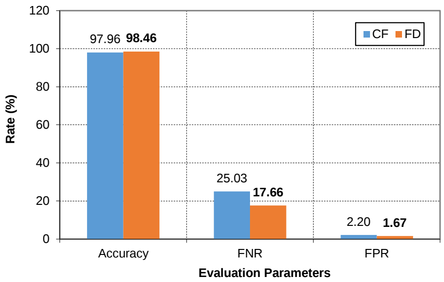
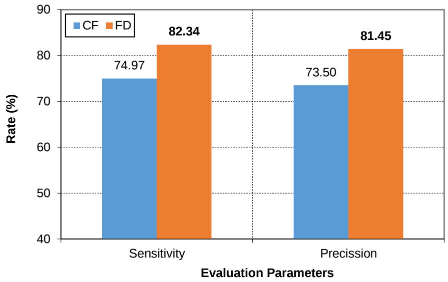


Figure 8. Example of face images variations for real time evaluation.



(a) Acuracy, FNR, and FPR



(b) Sensitivity and precision

Figure 9. Performance of real time experiments.

which is indicated by more than 98% of accuracy and less than 2% and 18% of FPR and FNR, respectively (see Fig. 9(a)). These performances can be achieved because the developed recognition engine using the face descriptor of the DCT and sub-space analysis provides well data separation. Compared to the performance of CF based face recognition, our proposed method significantly decreases the FNR by about 7.37% and in another side, it is not much increase and decrease the accuracy and FPR, as presented in Fig. 9(a).

The FD based face recognition engine also improves significantly sensitivity and precision of CF based face recognition by about 7.37% and 7.95% respectively, as shown in Fig. 9(b). It also affirms that our proposed method can handle the false negative problem of the baseline method (the correct person is falsely recognized as others). Overall, the real time performances confirm the off-line achievements which can improve the baseline performances.

The last experiment was carried out to know the performance of FD based face recognition engine for door locking system which was done by the staff of Informatics Engineering Dept., Engineering Faculty, Mataram University, in one week. The door locking system can work properly, which is shown by the accuracy, FPR, and FNR by about 98.30%, 21.99%, and 1.8%, respectively. The last result also re-affirm that the FD is powerful for real time face recognition engine.

4. Conclusion and Future Work

The real time FD based face recognition engine gives better performances than those of baseline (CF). From the Off-line evaluations, it provides high recognition rate (average more than 96%) for all tested datasets, while the real time experimental data provide high accuracy (more than 98%) and less false verification rate (by about 17.66% of false negative and 1.67% of false positive rate). Regarding the computational time, the proposed electronics key simulator needs less than 1 second for the matching process. In addition, the application of FD face recognition engine for the door-locking system also works properly, which is indicated by 98.30%, 21.99%, and 1.8% of accuracy, FPR, and FNR respectively.

The door-locking system based on face image has to be evaluated in large size dataset to know its robust performance against the large variability of face images in pose, lighting, and accessories. In addition, the proposed system still needs to be improved by adding some illumination compensation, such as Contrast Limited Adaptive Histogram Equalization (CLAHE) to decrease the false negative recognition.

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