A Novel Preprocessing Approach for Human Face Recognition Invariant to Illumination

U.K. Jaliya and J.M. Rathod

Abstract Human Face recognition is one of the widely used biometric techniques for face identification and verification. It includes several subproblems like illumination variation, expression changes, aging, occlusion, and rotation of face images. Varying illumination is one of the well-known and challenging problems in human face recognition applications. In this paper, we proposed a novel approach to solve varying illumination problems in face images. The different stages include adaptive histogram equalization (AHE), Gaussian filtering, Log transform, difference of AHE+Gaussian filtering+Log image, and AHE+Log image, and then, we perform normalization. We are using principle component analysis (PCA) method for face recognition. The experimental results of proposed approach are compared with existing approaches, and it shows that our approach improves the performance of recognition under varying illumination conditions on Yale Face Database B.

Keywords Adaptive histogram equalization (AHE) · Principle component analysis (PCA) · Yale face database B · Gaussian filter · Log filter

1 Introduction

A biometric recognition system is an automated system that verifies or identifies a person's identity using a person's physiological characteristics and/or behavioral characteristics [1]. Face recognition has been growing rapidly in the past few years for its multiple uses in the areas of law enforcement, biometrics, security, and other

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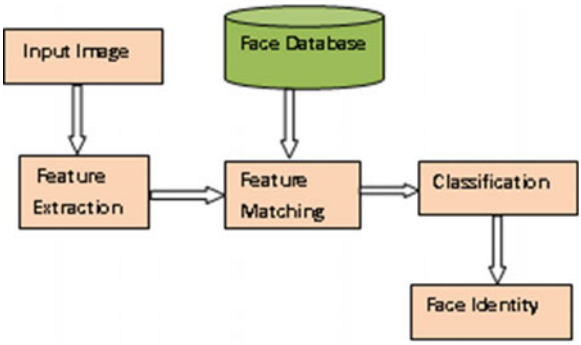


Fig. 1 Face recognition system [3]

commercial uses. As one of the most successful applications of image analysis and understanding, face recognition has recently gained significant attention, especially during the past several years. There are at least two reasons for such a trend: The first is the wide range of commercial and law enforcement applications, and the second is the availability of feasible technologies after several years of research. Face is one of the most common parts used by people to recognize each other [2].

The general block diagram for any face recognition system is given in Fig. 1. General steps in any face recognition system as depicted in Fig. 1 are discussed below:

The topic seems to be easy for a human, where limited memory can be a main problem, whereas the problems in machine recognition are manifold. Some of possible problems for a machine face recognition system are mainly [3]:

1. Facial expression change: A smiling face, a crying face, a face with closed eyes, and even a small nuance in the facial expression can affect facial recognition system significantly.
2. Illumination change: The direction where the individual in the image has been illuminated greatly affects face recognition success. A study on illumination effects on face recognition showed that lighting the face bottom up makes face recognition a hard task.
3. Aging: Images taken some time apart varying from 5 min to 5 years change the system accuracy seriously.
4. Rotation: Rotation of the individual's head clockwise or counter clockwise (even if the image stays frontal with respect to the camera) affects the performance of the system.
5. Size of the image: A test image of size 20 × 20 may be hard to classify if original class of the image was 100 × 100.
6. Frontal versus profile: The angle in which the photo of the individual was taken with respect to the camera changes the system accuracy.

2 Novel Approach for Preprocessing

2.1 Introduction

In our novel approach for preprocessing, the input image is given as an input to the adaptive histogram equalization (AHE). It computes the histogram of a local image region centered at a given pixel to determine the mapped value for that pixel; this can achieve a local contrast enhancement. The output of the AHE is given as an input to the Gaussian filter. The Gaussian smoothing operator is a 2D convolution operator that is used to 'blur' images and remove detail and noise. It uses a different kernel that represents the shape of a Gaussian ('bell-shaped') hump.

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{1}$$

where σ is the standard deviation of the distribution and $G(x, y)$ is the image. In our experiment, we have used $\sigma = 0.5$. The Gaussian is a high-pass filter, so it will remove low frequency and blur the image. The output image of AHE+Gaussian is given as an input the Log transformation. Logarithmic transformations enhance low gray levels and compress the high ones. They are useful for non-uniform illumination distribution and shadowed images. Then, we are taking the difference of AHE+Gaussian+Log image and AHE+Log image, and finally, we perform normalization on the output image, so it will give the illumination-free image. The entire procedure is depicted in Fig. 2.

Our novel preprocessing approach output is given as an input to the face recognition system. Here, for experiment, we are using PCA method for face recognition and Euclidean distance as a classifier.

2.2 Face Database and Experimental Results

To illustrate the performance of our approach, we have conducted face recognition experiments using the Yale Face Database B. The database consists of images taken under 64 different lighting conditions, which are divided into 5 subsets according to

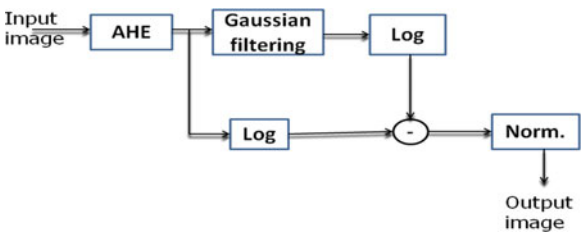


Fig. 2 Block diagram of a novel preprocessing approach

Fig. 3 Example of Yale B subset sample images

lighting angle. In Fig. 3, we show examples of face images in each subset. We used 640 images in total taken of 10 individuals in a frontal pose.

In our experiments, we use five subsets and each subset has different number of images with same lighting angle. These subset images are used for training set, and we are selecting few images within the same subset for test images. Figure 4 shows the output of each steps of Fig. 2, a novel approach block diagram.

From Fig. 4, we can see that the normalized image is the illumination-free image as compared to input image. Figure 5 shows the original images and output of our novel approach images. Row-1 shows original images, and row-2 shows processed images with our novel approach.

We have selected some of the images from the subsets as training set and testing set images. These images are used for face recognition using PCA method, and we

Fig. 4 Output of each steps of novel approach

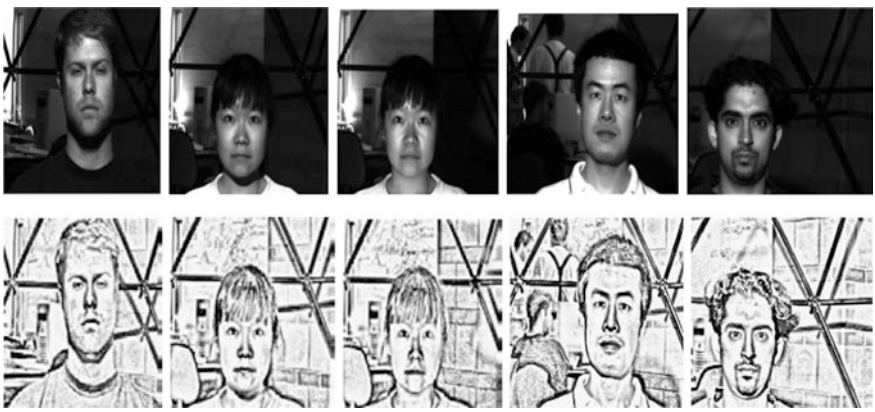


Fig. 5 Original images and novel approach output images

Table 1 Recognition rate

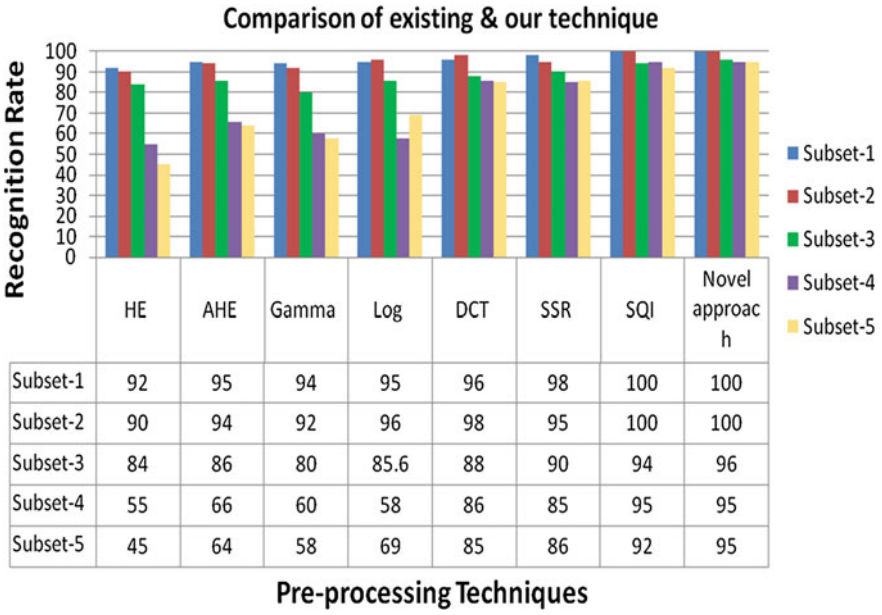
Subset	# of train images	# of test images	Recognition rate (%)
1	110	30	100
2	80	20	100
3	95	25	96
4	80	20	95
5	140	40	95

have calculated recognition rate as shown in Table 1: first column shows subset number, second shows number of training set images, third shows number of testing set images, and last column shows the recognition rate.

2.3 Comparison with Existing Methods [1–14]

Our novel preprocessing approach is compared with other approaches suggested by various others for face recognition using Yale Face Database B. Figure 6 shows the comparison of preprocessing approaches graphically. The graph in Fig. 6 indicates recognition rate in percentage.

From Fig. 6, we see that our method give good recognition rate compare to existing preprocessing techniques.



	HE	AHE	Gamma	Log	DCT	SSR	SQI	Novel approach
Subset-1	92	95	94	95	96	98	100	100
Subset-2	90	94	92	96	98	95	100	100
Subset-3	84	86	80	85.6	88	90	94	96
Subset-4	55	66	60	58	86	85	95	95
Subset-5	45	64	58	69	85	86	92	95

Fig. 6 Comparison of various preprocessing approaches

3 Conclusion

In this paper, we presented a novel approach for preprocessing to illuminate the lighting effect from the face images. The experiment results show that our approach can significantly improve the recognition rates of face images under different lighting conditions compared with existing approaches. The recognition rate claimed by each of researcher depends on the database used and the number of subjects on which recognition task has been performed.

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