PCA in the context of Face Recognition with the Image Enlargement Techniques

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Abstract—**Face recognition has become a field of interest in many applications such as security and entertainments. In surveillance system, the quality of the recoded footage is sometimes insufficient due to the distance and angle of the camera from the scene. This causes the object of interest, e.g. the face of a person in the scene to be of low resolution, which increases the difficulty in recognition process. Image resolution enhancement is a potential solution for enlarging low-resolution images for real time face recognition. An enlarged image is then compared to available database of images to either identify or verify the individuals. However, the optimal performance of face recognition techniques when various image enlargement methods have been applied to them has not been investigated. In this research, the performance of PCA based face recognition method, with the three most well-known image enlargement techniques (Nearest Neighbour, Bilinear, Bicubic) is investigated. First, an input image is down sampled to six different resolutions. The down-sampled image is then enlarged to its original size using the three named image enlargement techniques. The enlarged image is then input to a PCA face recognition system for the recognition process. The simulation results using images from the SCFace database show that PCA based face recognition illustrates superior results when input images enlarged using Nearest Neighbour technique, while the performance of Bicubic and Bilinear techniques is slightly lower than Nearest Neighbour method.**

Keywords- Image Enlargement; Face Recognition; Image Interpolation; Principle Components analysis

I. INTRODUCTION

Over the last two decades, there has been a growing demand to authenticate individuals, based on biometrics characteristics [1]. Traditional means of automatic recognition, such as passwords or ID cards, can be forged. Since biometrics are based on individuals' physiological and behavioral characteristics, they are universal, unique, permanent, measurable and hence more difficult to be stolen and faked. There has been many researches in using biometrics for people recognition, such as finger print recognition, ear recognition, palm recognition, iris recognition and face recognition [2-3].

Face recognition has developed rapidly over the past decades, gaining wider acceptability both in government and commercial technologies. This owes to face recognition's security application in areas such as airports and international border agencies for identity check, automated surveillance systems and social media as well as plastic surgery face recognition [4-5]. Face recognition has proven to be the most suitable human biometrics for automated identification due to the fact that, it offers a balance between reliability and social acceptance. The human ability to recognize faces of individuals is by far greater than any machines or algorithms. However, when it comes to recognize an individual from a large dataset of face images, it is a tedious task for a human to easily identify one individual. A face recognition system is essentially a pattern recognition system that operates by acquiring a face image from an individual, extracting certain features (defined as mathematical artifacts) from the acquired data, and comparing this feature sets against a template of features already acquired in a database [6].

Principal Component Analysis (PCA) is a widely used mathematical tool proposed by Karl Pearson in 1901 for data analyses and development of predictive models. Turk and Pentland [7] were first to propose the application of PCA technique in face recognition. Further researches confirmed that PCA is one of the most popular and widely used face recognition techniques [8-13]. In PCA based face recognition method, each face image is represented as an algebraic sum of the weighted Eigen vectors (Eigen-faces). The Eigen vectors were then compared with calculated Eigen vectors of each image in the database. Different techniques such as Sum of Absolute Difference (SAD) is used to identify the closest match in the database or conclude that there is no match with the available images in the database.

In automated surveillance system, a watch list of images is first created, processed and stored in a database. Input images acquired from a digital camera are fed to the recognition system. The recognition algorithm compares the input image with the images in the watch list database and generates a result on whether the input image matches with any previously stored images. However, the acquired video surveillance footage, with specific face part may be of low-resolution images, which pose a challenge on the performance of the face recognition system [14].

Surveillance cameras and mobile device embedded cameras have been a major source of information for forensic/criminal investigations. Digital image/video footage of the crime scene

can be used to identify the criminal/s. However, the quality of the recoded image/video footage is sometimes insufficient for face recognition purpose due to the distance and angle of the camera from the scene. This causes the face of a person in the scene to be of low resolution which increases the difficulty of the recognition process. Hence, the performance of face recognition systems is highly benefited from the application of image/video resolution enhancement techniques to improve the quality of the image. PCA based face recognition techniques do not perform well when low resolution images are input to the system. Therefore, an image enlargement technique is a potential solution for enlarging the low-resolution input images in face recognition system. However, the performance of PCA face recognition has not been investigated with various enlargement techniques.

Traditional image interpolation methods such as Bilinear, Bicubic, B-spline and nearest neighbourhood and adaptive interpolation algorithms are widely used for resolution enhancement in different applications, e.g. communication and surveillance [14]. Adaptive interpolation techniques produce superior image quality compared to traditional image interpolation methods in terms of computational complexity and processing speed. In [14] authors presented a performance comparison between various traditional image interpolation techniques. The quality of the output images produced from all techniques showed that the images enlarged using Nearest Neighbour method have the highest aliasing effect, whereas Bilinear technique produces images with reduced aliasing effect and blurring edges. Bicubic and cubic B-spline images have moderate aliasing and blurring effect, with edge halo effects.

In this paper, the performance of PCA face recognition technique when Nearest Neighbour, Bilinear and Bicubic image enlargement methods have been used to enlarge input images with different resolutions, are investigated. Results shows that the PCA based face recognition method achieves its highest performance when it uses Nearest Neighbourhood image enlargement algorithm to generate the super-resolution image in comparison to other two enlargement techniques. The rest of the paper is organized as follows: the system setup of PCA face recognition with various image enlargement techniques is presented in Section II; experimental results are discussed in Section III and finally paper will be concluded in Section IV.

II. PCA FACE RECOGNITION WITH VARIOUS IMAGE ENLARGMENT TECHNIQUES

Figure 1 shows a block diagram of the proposed PCA based face recognition system. From this figure it can be seen that it first converts the input image into its Eigen-face vector and then it normalised the resulting Eigen-face vector. The normalised Eigen-face vector is then projected onto the Eigen-space to determine the weighted vector of the input image. The distance between the weighted vector of the input image and every other image in the database is calculated. If the difference, i.e. the distance between the weighted vector of the input image and every image in the database, are greater than a predefined threshold value, it implies that there is no match for the input image in the database. Moreover, the image with the lowest

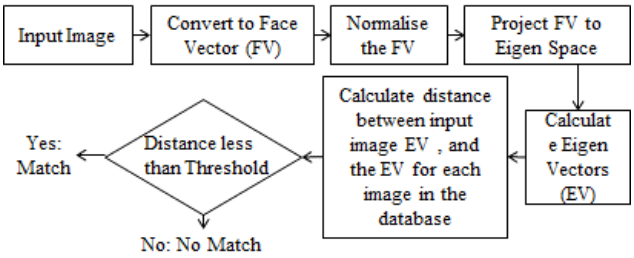

Figure 1. Block diagram of a PCA face recognition process

distance is identified as the closest image or the best match of the input image.

A. PCA Face Recognition Technique

Assume F is a set of images of the same size and $F = f_1, f_2, \dots f_N$. For each image $f \in F$, a mean adjusted image f' is created as follows [15]:

$$f' = f - \bar{f} \tag{1}$$

where F is the mean value of the pixels in image f. Every image f' is then converted to a column wise vector, allowing F to be represented as a two dimensional matrix S. PCA is then performed using Singular Value Decomposition (SVD) on matrix S creating the following decomposition:

$$S = U \sum V^T \tag{2}$$

where U is a unity-matrix and the columns of V are the orthonormal eigenvectors of the covariance matrix of S and $\sum$ is a diagonal matrix of their respective eigenvalues. The eigenvectors form a basis for an eigenspace for each set of images F. The resulting principal components in V are finally used for matching, as follow:

Let $M = m_1, m_2, \dots m_{N-1}$ be the set of principal components of a query image q and let r be an image in the dataset of images R with principal components $L = [l_1, l_2, \dots l_{N-1}]$. Each Euclidean distance $d_n \in D = [d_1, d_2, \dots d_{N-1}]$ between q and r can be calculated using Equation (3):

$$d_n = \sqrt{\sum_n (m_n - l_n)^2} \tag{3}$$

After the calculation of the Euclidean distances between the principal components, they are averaged into an average distance metric, as written in E1uation 4:

$$AvD = \sum D/(N-1) \tag{4}$$

The best match for query image q in the image dataset R is the image for which AvD is minimized.

B. Image Resolution enhancement embedded in Face Recognition system

Figure 2, shows the image resolution enhancement set up, embedded into the face recognition system. 130 coloured face images of resolution 1024 x 1572 pixels obtained from SCface database of face images were used as the database of test images

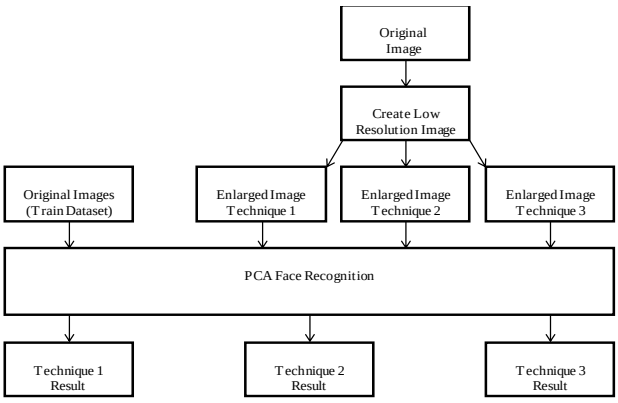

Figure 2. System Set up: Image Resolution enhancement embedded in Face Recognition system.

and training dataset for the face recognition algorithm. The same 130 images were down sampled to six different resolutions, creating six different sets of test images. Each of these six low resolution sets of test images were then enlarged back to their original size using the three traditional image enlargement techniques i.e. Nearest Neighbour, Bilinear, and Bicubic techniques. This set up carried out for six different resolutions (512 x 786, 256 x 384, 128 x 192, 64 x 96, 32 x 48, and 16 x 24 pixels), which produces eighteen result sets of 130 face images. The resulted images were used as input images for the face recognition experiment.

III. EXPERIMENTAL RESULTS

To observe the effect of enlarging input images, captured at various distances, using different image enlargement techniques on the PCA face recognition algorithm, 130 images from SCface database were used. The 130 images, with the original size of 1024x1572, were used to train dataset for PCA face recognition. The test images were first down-sampled to six different resolutions, 512x786, 256x384, 128x192, 64x96, 32x48 and 16x24 to generate six sets of input images. Figure 3 (a) - (f) shows one of the test images, 001frontal.jpg, which was down sampled to sizes mentioned above. Each set of the down-sampled images were then enlarged back to the original image size (1024x1572 pixels) using Nearest Neighbour, Bilinear, and Bicubic techniques. True Acceptance (TA) were used as a metric to measure the percentage accuracy of the recognition system. Table I presents the TA results of PCA face recognition algorithm when the input test images with the size of 1024x1572 were down-sampled to 512x786, 256x384, 128x192, 64x96, 32x48 and 16x24, respectively and then enlarged back to 1024x1572 pixels using the three image enlargement techniques. The percentage accuracy of the face recognition system (TA) is described as:

$$TA = \frac{number\ of\ matched\ images}{total\ number\ of\ gallery\ images} * 100\% \qquad (5)$$

It can be seen from the results that, the enlarged images of size 512x786 using the three image enlargement methods offer the same TA value of 69.23%. However, as the resolution decreases (which represents images captured at varying distance from for example a CCTV camera), the TA decreases unevenly with different enlargement techniques. The Bilinear technique shows a significant decrease in TA compared to the other two methods, followed by the Bicubic technique and finally the Nearest Neighbour. Figures 4, 5 and 6 illustrate the visual quality of enlarged down sampled 001Frontal test image with sizes of (a) 512x786, (b) 256x384, (c) 128x192, (d) 64x96, (e) 32x48 and (f) 16x24 back to 1024x1572 (original image size) using Nearest Neighbour, Bilinear, and Bicubic techniques respectively. The TA results in Table I and Figures 4, 5 and 6 (a), show that enlarging the input image by doubling its resolution using the three techniques has slight effect on the recognition accuracy and the visual quality of the enlarged images. TA results in Table I (size 256x384) and Figures 4, 5 and 6 (b) illustrates that with the decrease in the resolution of the images, the TA show a slight reduction for Bilinear technique, while the visual quality seems similar among the three techniques. The TA results for image sizes of 128x192 and

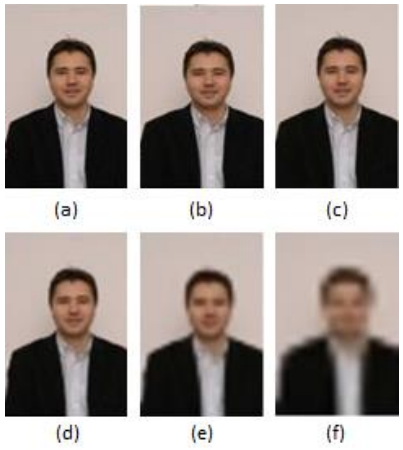

Figure 3. 001Frontal test image was down sampled to different sizes: (a) 512x786, (b) 256x384, (c) 128x192, (d) 64x96, (e) 32x48 and (f) 16x24

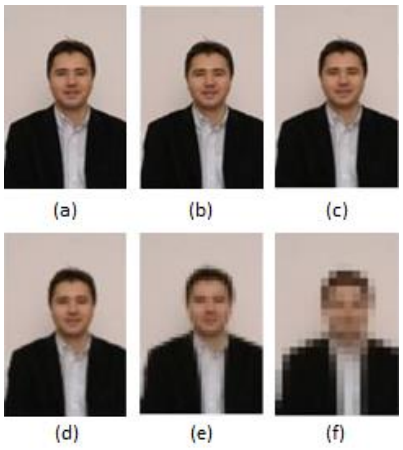

Figure 4. 001Frontal test image with sizes of (a) 512x786, (b) 256x384, (c) 128x192, (d) 64x96, (e) 32x48 and (f) 16x24, enlarged back to the original size of 1024x1572 using Nearest Neighbor technique.

TABLE I. PCA FACE RECOGNITION WITH INPUT IMAGES (RESOLUTION 1024X1572) DOWN SAMPLED TO DIFFERENT SIZES

TA (%): Image resolution 1024x1572 down sampled to:	**Interpolation methods**		
	Nearest Neighbour	***Bilinear***	***Bicubic***
512x786 resolution	69.23	69.23	69.23
256x384 resolution	69.23	68.46	69.23
128x192 resolution	69.23	68.22	68.46
64x96 resolution	68.46	65.39	66.92
32x48 resolution	56.72	49.23	56.15
16x24 resolution	26.15	22.31	25.39

64x96, show a decrease for input images enlarged using Bilinear and Bicubic while the Nearest Neighbour still maintaining the highest TA value. The visual quality of the test images in Figures 4, 5 and 6 (c and d) show slight blurs around sharp edges in Bicubic and Bilinear techniques, while Nearst Neighbour shows slight blocking arifacts on the face. Unlike the results so far, at resolution 64x96, nearest neighbour show a decreases in its TA results, however this technique still offers the best recognition TA results followed by the Bicubic technique and finally the Bilinear. Figures 4, 5 and 6 (e) illustrate visible blurs which well explained the results presented in Table I (substantial decrease in the recognition accuracy at resolution 32x48). Finally, the TA results (resolution 16 x 24) show a drastic drop across all the three techniques. Nearest neighbour still offers the better result. The enlarged images in Figures 4, 5 and 6(f) illustrate visible blurring artifacts in Bilinear, and Bicubic techniques and visible blocking artifacts in Nearest Neighbour. However, it seems blocking artifiacts produce less error in the face recognition percentage accuracy compared to blurring artifacts.

In summary, the results show that the recognition accuracy decreases differently with the three enlargement techniques

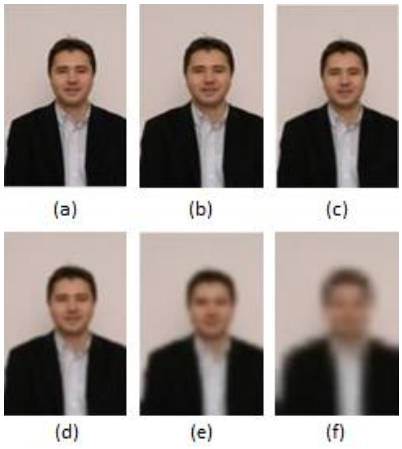

Figure 5. 001Frontal test image with sizes of (a) 512x786, (b) 256x384, (c) 128x192, (d) 64x96, (e) 32x48 and (f) 16x24, enlarged back to the original size of 1024x1572 using Bilinear technique.

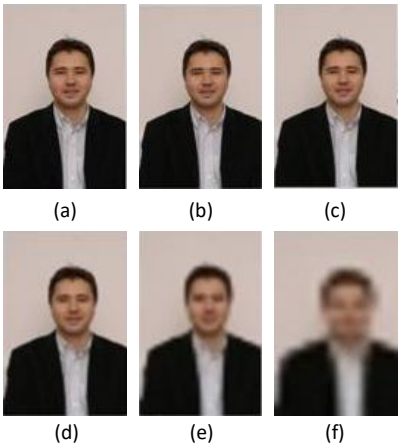

Figure 6. 001Frontal test image with sizes of (a) 512x786, (b) 256x384, (c) 128x192, (d) 64x96, (e) 32x48 and (f) 16x24, enlarged back to the original size of 1024x1572 using Bicubic technique

when the input image resolution decreases. Overall, it seems that the Nearest Neighbour constantly shows better performance in the PCA face recognition followed by the Bicubic and finally the Bilinear. Nearest neighbourhood has the least computationally complexity in its algorithm compared to the other two image enlargement methods. It is also observed that image enlargement techniques which offers the best visual image quality results for human vision may not offer the best result with computer algorithms. Thus, for optimum face recognition results in automated surveillance, there is a need to investigate the component algorithms i.e. algorithms for pre-processing input images and the face recognition algorithm to be used.

IV. CONCLUSIONS

This paper investigates the optimal performance of traditional image enlargement techniques in the context of PCA face recognition. Three well-known image resolution enhancement techniques (Nearest Neighbour, Bilinear, Bicubic) were used to enlarge a selected number of images from a data sets of images with different resolutions. The enlarged images were then input to the PCA face recognition system, and the three different image enlargement methods were applied to them. The simulation results show that PCA face recognition illustrates superior results when input images enlarged using Nearest Neighbour technique, while the performance of Bicubic and Bilinear techniques are slightly lower than Nearest Neighbour method.

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