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An Iterative Image Restoration Scheme for Degraded Face Images

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Abstract: Image restoration is a technique which restore the degraded face images such as faxed images, scanned passport photos and printed images by removing noise in the image. The degradations include half toning, dithering and security watermarks. An iterative image restoration scheme is used to restore the severely degraded face images which improve the recognition performance and the quality of the restored image. In this paper, we study Viola and Jones face detection algorithm which is to localize the spatial extent of the face and determine its boundary. In next step, geometric normalization is applied to both original and degraded images. It holds two processes namely automatic eye detection and affine transformation that matches the images in the database and constructs the canonical faces. Low pass filtering is done using Wiener filter which reduces the noise in the image and the invariant wavelet transform reduces artefacts. Then, the quality of the image is checked using some of the quality metrics and it is restored if the quality is good. Image identification before and after restoration is achieved using certain classification tools and methods. The experimental results demonstrate that our proposed system improved the recognition performance and quality of the image.

Keywords: Face restoration, face recognition, quality metrics, k-nearest neighbour classifier, neural network classifier.

I. INTRODUCTION

Image Restoration is used to reduce degradation effects in the image. Image restoration is based on filter design and is used to improve the appearance of an image. The sources of image degradation includes harsh ambient illumination conditions , low quality imaging devices, image compression down sampling, out-of-focus acquisition, device or transmission noise motion blur, halftoning, dithering, and the presence of security watermarks on documents. These types of degradations present in an image are observed in printed or faxed documents.

This paper deals with an automated face recognition scenario which involves comparing degraded facial photographs against their high-resolution counterparts. The types of degradation considered in this paper are: 1) fax image compression, 2) fax compression, followed by printing, and scanning, and 3) fax compression, followed by actual fax transmission, and scanning. In order to identify the legacy face photos which are acquired by the government agency that has been faxed to another agency The real time examples for this situation are scanned face images present in driver's licenses, refugee documents, and visas for the purpose of establishing or verifying the subject's identity.

The factors that impact the quality of degraded face photos are 1) person-related , eg: changes in hairstyle, expression and pose of an individual; 2) document-related, eg: lamination and security watermarks that are often embedded on passport photos ,change in image quality, tonality across the face and color cast of the photographs; 3) device-related, eg foibles of the scanner used to capture face images from documents, camera resolution, image file format, fax compression type, lighting artefacts, document photo size, and operator variability.

The goal of this paper is to match degraded face photos against high-resolution images and to restore the degraded photos .An iterative image restoration scheme is employed in which the objective functions namely peak signal-to-noise ratio (PSNR) and the Universal Image Quality Index (UIQ) to guide the image restoration process. The result is to generate restored images with high quality and to improve better recognition performance of the image.

The texture and quality based classification algorithm is used to determine the nature of degradation present in the image. This information is then used to generate the appropriate set of parameters for the restoration process. This helps the human operators in verifying the correctness of a match.

II. RELATED WORK

The existing works closely related to the problem of matching degraded face images against high resolution images. The problem addressed in existing models is based on two topics in the field of image processing

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namely 1) image restoration, 2) super-resolution. Most of the proposed techniques have given only implicit assumptions about the type of degradation present in the image and did not deal with degree of degradation in the images [1]. Without specifying the problem of restoring the image, only the quality and recognisability of the image was addressed. Matching high spatial resolution face image with low resolution image is encountered in the process of super resolution. The age difference between pair of face images is determined using Bayesian classifier. [2]. In the paper [3], [4] the images scanned and the images obtained using camera while comparing do not provide the required result.

III. FACE DETECTION

The image obtained is degraded due to many factors. The degraded image is stored in the database. The overall image restoration technique is shown in fig 1. Face Detection [fig 3] technique is used to extract only the face region from the image. It is done using a method, Viola and Jones face detection [5].

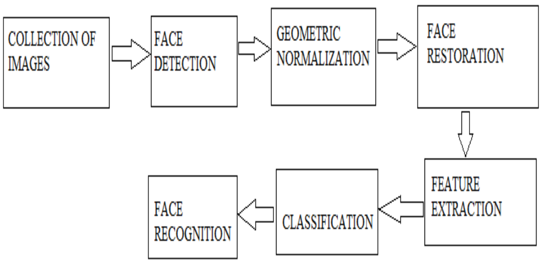

Fig 1: Architecture for image restoration

A. Viola and Jones face detection algorithm

The Viola and Jones face detection algorithm is used to detect the face. This method is faster and efficient in detecting the face. The rectangular haar like function is used to detect the face region in the image. The rectangular feature is used to locate the face and it eliminates the other regions. The haar feature is the sum of luminance of pixel position in white region to the sum of luminance in remaining gray section. The difference between them gives the rectangular feature and the detected face is shown in fig 2. The accuracy and speed is achieved by using Viola and Jones face detection algorithm.

Fig 2: Viola and Jones face detection algorithm

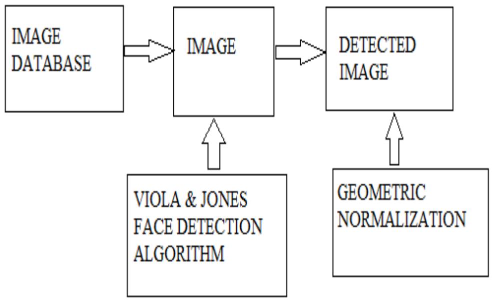

Fig 3: Face Detection

B. Geometric normalisation

The geometric normalisation is applied to the detected face image in fig 2. It comprises of automatic eye detection and affine transformation. The automatic eye detection is used to detect the eye coordinates in an image. The affine transformation is used to find the pixel position of an image in different angles. This method can be applied only to frontal images.

Using geometric normalisation figure 4 the pixels present in the image becomes comparable. For example, an image contains a mole or a scar the geometric normalisation makes the pixels present in the image comparable or even.

Fig 4: Normalised image

IV. FACE RESTORATION

After the pixel becomes equal, the normalised image is used for restoration. Image denoising [10] method is used to remove noise from the image.

A. Denoising using Wiener filter

In Wiener filter [fig 5], the filter value is incremented until the noise present in the image is removed. Wiener filter is otherwise called Minimum Mean Square Error Filtering. The other filtering approaches do not provide an explicit privilege for handling noise. But, Wiener filter uses both degradation function and statistical characteristics of noise for removing noise from the image and to restore the image. Its purpose is to reduce the amount of noise by comparing it with an estimation of the desired noiseless signal.

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The objective of Wiener filter is to find an estimate of the uncorrupted image such that the mean square error between them is minimized. It minimizes the overall mean square error in the process of inverse filtering and noise smoothing. The Wiener filter is better than other filters since it reduces the noise present in the image more effectively. The Wiener filter provides solutions for non casual filter, casual filter and finite impulse response filter.

The Wiener filtering executes an optimal trade-off between inverse filtering and noise smoothing. It removes the additive noise and inverts the blurring simultaneously. The Wiener filtering is a linear estimation of the original image. Wiener filter has two separate parts, an inverse filtering part and a noise smoothing part. The Wiener filter not only performs the deconvolution by inverse filtering (high pass filtering) but also removes the noise with a compression operation (low pass filtering).

Fig 5: Denoising using Wiener filter

B. Quality metrics

Signal to noise ratio (SNR): It is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power. A ratio higher than 1:1 indicates more signal than noise. Signal-to-noise ratio is defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal).

$$SNR(\hat{h},h_0) = -20.\log_{10}\frac{\|h_0\|}{\|\hat{h}-h_0\|} \quad (1)$$

Where, h_0 is the true image which is unknown and $\hat{h}$ is the restored image. The SNR can be obtained by calculating the square of the amplitude ratio:

$$SNR=\frac{P_{signal}}{P_{noise}}=\left(\frac{A_{signal}}{A_{noise}}\right)^2 \quad (2)$$

Where, *A* is root mean square (RMS) amplitude. In decibels, the SNR is defined as

$$SNR_{dB}=10\log_{10}\left(\frac{P_{signal}}{P_{noise}}\right)=P_{signal,dB}-P_{noise,dB} \quad (3)$$

Which may equivalently be written using amplitude ratios as

$$SNR_{dB}=10\log_{10}\left(\frac{A_{signal}}{A_{noise}}\right)^2=20\log_{10}\left(\frac{A_{signal}}{A_{noise}}\right) \quad (4)$$

Peak signal to noise ratio is most commonly used as a measure of quality of reconstruction of lossy compression codec's (e.g., for image compression). The signal in this case is the original data, and the noise is the error introduced by compression. This measure is defined as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The formula for calculating PSNR is,

$$PSNR(\hat{h},h_0) = 10.\log_{10}\frac{MAX_i\ 2}{MSE(\hat{h},h_0)} \quad (5)$$

Where, $MSE(\hat{h},h_0)=E[(h_0-\hat{h})^2]$ is the error of the restored image($\hat{h}$) corresponding to the true image(h_0). MSE is the mean square error.

Universal image quality index is the measure proposed in was designed to model any image distortion via a combination of three main factors, viz., loss of correlation, luminance distortion, and contrast distortion [6].

The formula for calculating UIQ is as follows,

$$UIQ=\frac{\sigma_{xy}}{\sigma_x\sigma_y}.\frac{2\bar{x}\bar{y}}{\bar{x}^2\bar{y}^2}.\frac{2\sigma_x\sigma_y}{\sigma_x^2\sigma_y^2} \quad (6)$$

where, x=true image

y=restored image

$\bar{x}$, $\bar{y}$=means of x and y

σ_x^2, σ_y^2=variances of x and y

σ_{xy}= covariance of x and y

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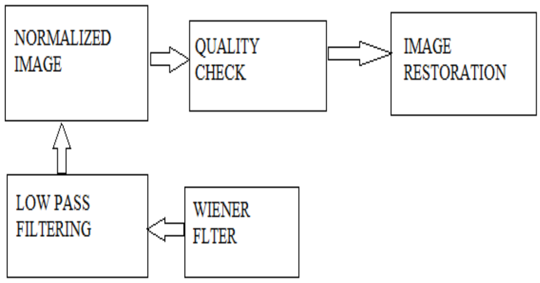

Fig 6: Face restoration

The iteration takes place until the image obtained satisfies the quality metric based objective functions. The restored image is then used for recognition. The face restoration process on the normalised image using wiener filter and quality metrics is shown in fig 6.

V. FACE RECOGNITION

The face recognition is performed using neural network classifier shown in fig 7. The neural network classifier consists of hidden layers. The input which is the feature (X) extracted from the image is given for the process and the output is obtained. The neural network classifier uses,

$$X .w \pm b = class$$

Where w and b are the weight and bias values which are incremented until the image present in the test database (degraded image) is matched with trained database (original image).

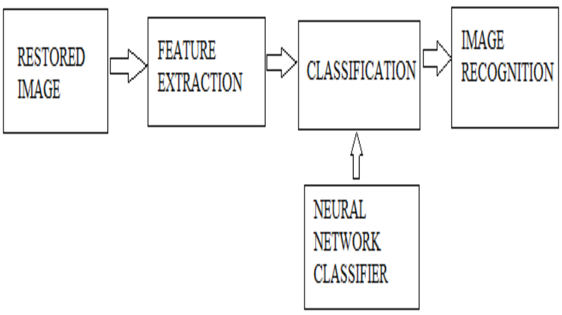

Fig 7: Face Recognition using neural network classifier

In neural network classifier, a train database and a test database is maintained. The train database contains original images and a test database contains degraded or noised face images. The feature extraction is done from both test and train database based on G8, CSU [7], LBP [9] methods.

Finally, the classification is done using neural network classifier shown in fig 8. The high resolution and restored images were compared

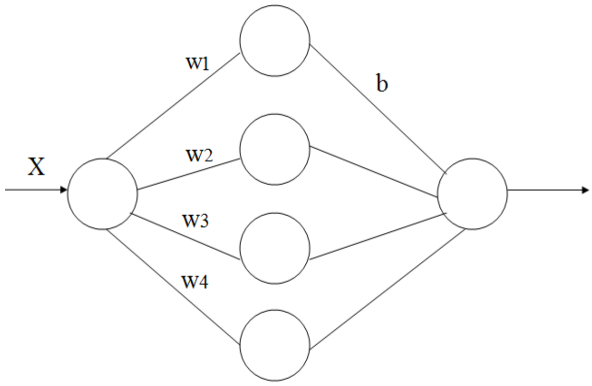

Fig 8: Neural network classifier architecture

VI. EXPERIMENTAL RESULTS

In this section, we present a set of experiments used to evaluate the efficiency, scalability and robustness of our system in comparison with existing ones. The experimental result is presented in this section.

A. k-nearest neighbor classifier

The k-Nearest-Neighbor Classifier [8] is unable to predict the correct image. The person present in the image is a twin and if these images are stored in the database, the classifier based on some common similarities or distance assigns the nearest neighbour image to be the correct image. So, this problem is overcome by our proposed system using neural network classifier.

B. Neural network classifier

In neural network classifier, a train database holds original image and a test database consists of noisy images is maintained. Here, after extracting the features from the image, several iterations are performed using weight and bias values till the restored image is recognized. The fig 9, 10 and 11 shows the quality of the restored image using quality based objective metrics.

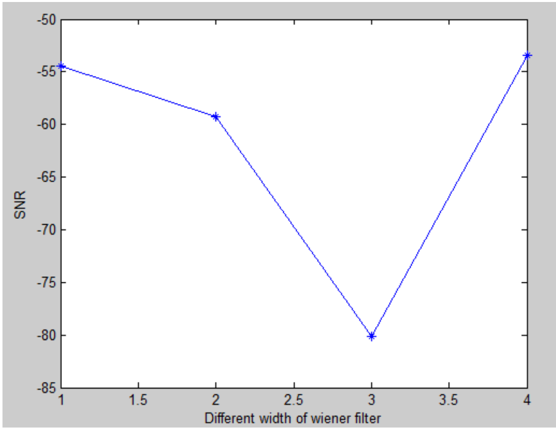

Fig 9: Performances of SNR

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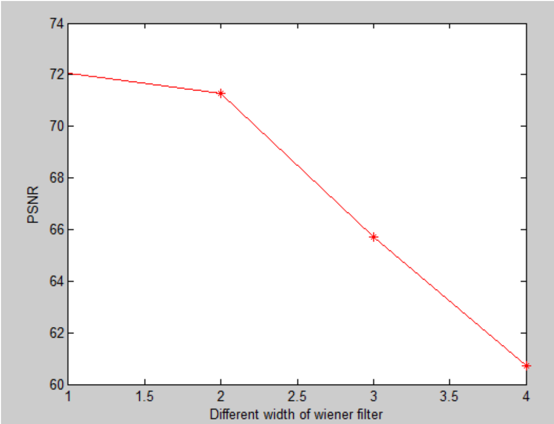

Fig 10: Performances of PSNR

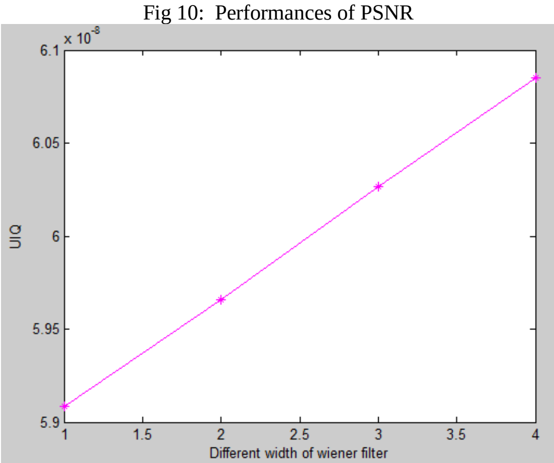

Fig 11: Performances of UIQ

Thus the quality and recognisability of the restored image is improved.

VII. CONCLUSION

We have studied the problem of restoring severely degraded face images. The proposed restoration methodology consists of iterative method to restore the noisy images and that is compared with the high resolution counterparts. Our proposed work uses neural network classifier to recognize the image which is restored with that of the original image. Experimental results show that the face recognition is achieved better in neural network classifier than that of k-nearest neighbour classifier used in the existing model.

One of the possible improvements could be made is the use of super-resolution algorithm which helps to know about the prior on the spatial distribution of the image gradient for frontal face images. Another future work to be done is the better classification of the degraded face images which will improve the integrity of the overall restoration technique.

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