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Research paper

A Comparative Analysis of Quality Metrics between Different Image Enhancement Techniques for Facial Sketches

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Abstract

Enhancement of an image is considered as one of the important aspect in image processing. It is also considered to be major pre-processing step which is used in vision systems and lot many image processing applications. It is used in law enforcement application such as in crime investigation process, identification and apprehension of criminals by matching facial sketches to the mug-shot photos. Here skilled forensic artists are used to draw sketches based on the vocal description provided by the victim or eye witness. The sketches drawn might be blurred, less quality images. So to measure the quality of sketches, here three quality assessment methods are used in this study such as PSNR (Peak Signal-to-Noise Ratio), MSE (Mean Squared Error) and the SSIM (Structural Similarity index). Hence this paper aims in discovering a better image enhancement technique for the sketches from different databases by comparative analysis of aforesaid quality metrics along with their time complexity factor. The method has considered both viewed sketches and composite sketches as a source of input.

Keywords :*Facial Sketches, Enhancement techniques, Quality metrics, PSNR, MSE, SSIM, Time complexity.*

1. Introduction

Image enhancement is a way of improving an image which includes the process of adjusting digital images with the goal that the outcomes are more appropriate for display or further image analysis. Therefore it is an important pre-processing step which is used in vision systems and various image processing applications. Modifying the images such that the visual content present in the image is improved for human or machine recognition is the main intention of enhancing an image.

The major prerequisite for all vision and image processing techniques deals with creating digital images having good contrast and details regarding it. There are mainly two types of image enhancement methods, 1)Spatial domain- direct operation on pixels is performed and 2)Frequency domain- converts an image to Fourier transform for its operation [1]. As a result, image enhancement has been used in various image processing applications such as in identifying the criminals, security applications, robot vision system, consumer and various other applications to provide a better enhanced image.

In law enforcement application such as in identification of criminals by matching facial sketches of the suspect with the database of the facial photos, the sketches provided may be blurred, poor quality sketches which are drawn by sketch artist using the vocal description given by the victim or eyewitness. So in order to improve the quality and appearance of sketches different image enhancement techniques can be used. Sketches are categorized as, 1)***Viewed sketches-*** By directly looking at the person or his/her photo sketches will be created. Viewed sketch quality will be higher when compared to other sketches.

2)***Semi forensic sketches***-These sketches are drawn from photo image of a person based on his/her recollection of the sketch artist.

3) ***Forensic sketches-*** Which are sketched by obtaining eyewitness's description about the suspect.

4)***Composite sketches***- Which are generated with the help of some face composite software. This software provides a predefined set of human facial components. Based on witness description of the suspect individual face components are selected and merged together to form a facial image [2] [3].

Image quality metrics is used to measure and determine quality of images after the process of enhancement, compression or conversion on the sketches. Here we consider three metrics for the quality measurement such as PSNR, MSE, SSIM are applied to the sketches and results are obtained [4]. Based on the aforesaid quality metrics along with their time complexity factor a better enhancement technique for sketches is verified.

In this paper section II involves the review of literature. Section III gives detailed description on the architecture of proposed system. The analysis and results of the experiment, conclusion is described in section IV and V.

2. Literature Review

Narinder Kaur, et al [1] presents an overview of image enhancement techniques, briefly discusses about spatial domain, frequency domain for gray scale images. Hence gives better approach for future research. It also presents different transformations and filters that have been used by the researchers to enhance the image by improving its features such as brightness, noise removal and contrast etc.

Kipli, K., et al [4] has explained about the performance methods to determine the quality of image. Three assessment methods such as PSNR, MSE and SSIM are being used here. SSIM is said to have better correlation characteristics among the other assessment methods. Development of an efficient image quality assessment method was achieved.

Cheng, Y., Pedersen, M., & Chen, G. [5] has focused on the enhancement of images by using sharpening technique. Experimental results provides a psychometric analysis which was designed for the observers to evaluate and give scores to different images which is enhanced by using sharpening technique.

Lal, S., & Chandra, M. [6] the contrast enhancement of natural images by using an efficient algorithm is demonstrated, which consists of two main stages: 1)The image with poor quality is processed by altered sigmoid function. 2)To enhance the contrast of images obtained from the output of previous stage is again processed by using CLAHE (Contrast Limited Adaptive Histogram Equalization) method. Proposed algorithm performs efficiently for both bright and dark images.

de Freitas Zampolo, R., & Seara, R. [7] here three image quality metrics such as: MSE, NQM (Noise Quality Measure), SIM(Structural Information Metric) are compared under practical conditions so as to evaluate the performance between these metrics. Experimental results are provided for performance with their statistical indices. MSE based quality metric surpasses among the three image quality metrics.

Suneetha, M. I., & Venkateswarlu, D. T [8] proposed a technique in spatial domain for image enhancement by improving the contrast of images using a linear Parameterized Gradient Intercept Model. Experimental results provide good results for both true color and gray scale images, and is used in various image processing applications for various enhancement levels.

Stark, J. A. [9] proposed a new technique for improving the contrast of image known as AHE (Adaptive Histogram Equalization) based on the observation of HE. To develop a grey level mapping of image from the HE a key feature known as cumulation function was used here.

Ruikar, J. D., et al [10] presented a review on various types of image quality assessment methods. A separate database with twelve variations of images was created along with the original image. For the aforesaid database eleven image quality metrics was used and hence index of the image quality was estimated.

3. Proposed System

The main purpose of this work is to obtain a better quality sketches by making use of different image enhancement techniques and to measure the quality metrics, time complexity of the resulting enhanced sketches. Sketches belong to different modality and thus they are different from photographic images. The obtained sketches might blurred, low quality sketches. Thus image enhancement algorithms are useful to improve the performance of facial recognition, so that the resultant image is much more capable than the original image which enhances the image properties like edges, contrast or boundaries to make a graphic display more easier for the purpose of analysis.

The methodology of the proposed system is as shown in Fig. 1.

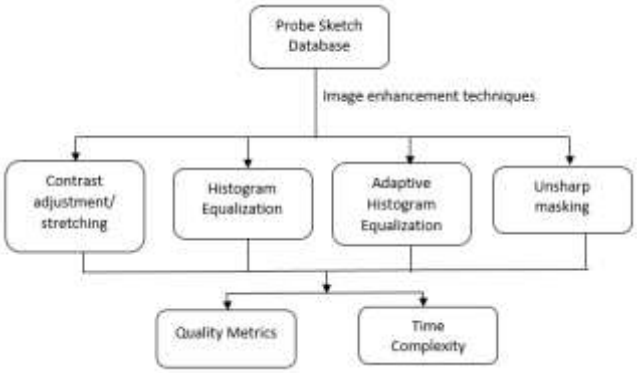

Fig.1: Methodology of Proposed system

Here in our work four types of image enhancement techniques are being used for two types of datasets such as CUHK, PRIP_HDC datasets.

3.1 Contrast Adjustment

It is a type of image enhancement technique where an image with good contrast will have sharp differences between black and white, whereas it will have insufficient contrast variation when there is no much keen difference between black color and white color. So the overall darkness or lightness of an image can be referred to as brightness. The process which maps the values of the pixel below a value that is specified to black i.e dark and pixel values higher than a value specified to white i.e light of an image is known as contrast stretching.

3.2 Histogram Equalization

It is the most common algorithm applied for image contrast enhancement. It is used to normalize the illumination on the face. It helps in improving the contrast area of an image from lower contrast to higher contrast. HE is a contrast enhancement method where it remaps the pixel values of input image such that the processed image has a uniform histogram as possible.

3.3 Adaptive Histogram Equalization

It is one of the image contrast enhancement method used for improving the contrast in images that has low contrast and to bring out more detail in the image. The issue of noise amplification in an image is addressed by a conceptual method of AHE which is called as CLAHE.

3.4 Unsharp Masking

It is a type of image enhancement method used for sharpening the edges of an image. In digital images, unsharp masking is said to be a simple and popular technique used for sharpening and contrast enhancement. To create an image that is less blurred when compared to the input image is performed by the technique of unsharp masking which makes use of a blurred or negative image to create a mask of input image, and then it is combined with the input (positive) image. Thus the unsharp masking technique is controlled by three main settings such as amount, radius and threshold. The formula is given by Eq. (1),

Sharpened = original + (original-blurred)*amount (1)

The below shown figures (2), (3), (4) describes about the different enhancement techniques being applied to the given input sketch for the CUHK, PRIP_HDC dataset sketches.

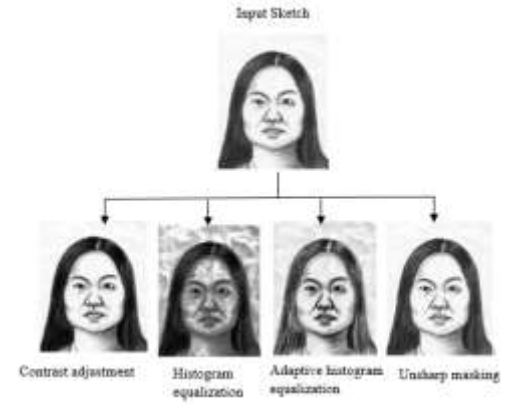

Fig.2: Enhancement of sketches using different enhancement techniques for CUHK dataset

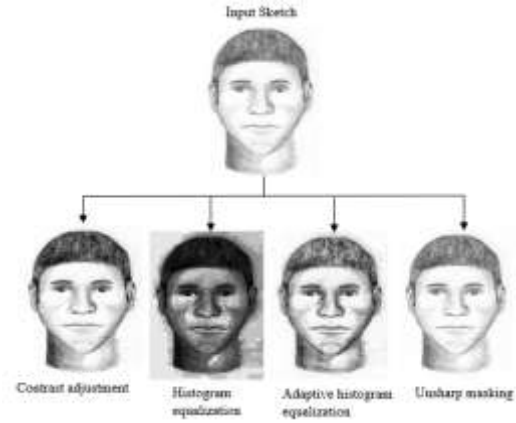

Fig.3: Enhancement of sketches using different enhancement techniques for PRIP_HDC dataset

4. Results and Discussions

The experiments are simulated in the MATLAB 2016a software. This paper aims in discovering a better image enhancement technique for the sketches from different datasets by comparative analysis between quality metrics along with their time complexity factor. The method has considered both viewed sketches and composite sketches as a source of input for CUHK (Chinese University of Hong Kong) [14], PRIP_HDC (Pattern Recognition and Image Processing Hand Drawn Composite) [15] datasets with 10 sketches each.

Three quality assessment methods are used in this study such as PSNR, MSE and SSIM to measure the quality of sketches along with time complexity factor.

CUHK DATASET

TABLE I :Comparison of Quality Metrics for CUHK Dataset

Image Enhancement Techniques (CUHK dataset)	Quality Metrics		
	PSNR	MSE	SSIM
Contrast adjustment/stretching	23.66283	284.30709	0.94412
Histogram Equalization	11.50878	4844.29498	0.48506
Adaptive Histogram Equalization	18.71275	890.71283	0.81529
Unsharp Masking	29.8898	66.93259	0.95904

The above Table I illustrates the different quality metrics along with their average values for various image enhancement techniques of CUHK dataset. And the quality measures used in our work are described as follows,

PSNR- Basically the mentioned technique is used as a way of measuring the ratio between the highest power that is possible of a signal and the power of noise under computation that affects the fidelity of its representation. Formula for PSNR is given by Eq. (2),

$$PSNR = 10\log_{10}(peakval^2 / MSE) \quad (2)$$

Where peakval is Peak Signal Value.

MSE- This measures the overall average of the errors in squares or its deviations i.e. the difference between what is estimated and estimator. It is always positive and values that are closer to zero are always better. Formula for MSE is given by Eq. (3),

$$MSE = \frac{\sum_{M,N}[I_1(m,n) - I_2(m,n)]^2}{M * N} \quad (3)$$

Where M, N are the number of rows and columns of input image.

SSIM- One of the method for forecasting the perceived quality of videos and images in digital format. It is used for measuring the equality factors between two images. The SSIM is the calculation or forecasting of quality of digital image based on an initial uncompressed or distortion free digital image as a point of reference. It is used to improve on traditional methods such as PSNR and MSE. Formula for SSIM is given by Eq. (4),

$$SSIM(x,y) = \frac{(2*\mu_x*\mu_y + c_1)*(2*\sigma_{xy} + c_2)}{(\mu_x\wedge 2 + \mu_y\wedge 2 + c_1)*(\sigma_x\wedge 2 + \sigma_y\wedge 2 + c_2)} \quad (4)$$

Where μ_x and μ_y is average of x and y, σ_x and σ_y is variance of x and y, σ_{xy} is covariance of x and y.

The below shown graphs represents the plot for PSNR, MSE and SSIM values of CUHK dataset.

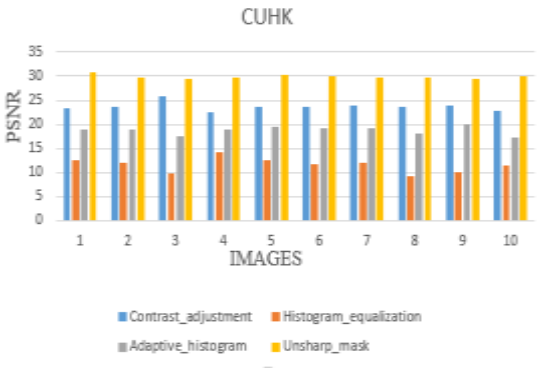

Fig.4: Plot for analyzing PSNR values with CUHK dataset sketches

The above fig. 4 represents that PSNR values are high for the sketches corresponding to Unsharp Masking and low for the Histogram equalization image enhancement technique.

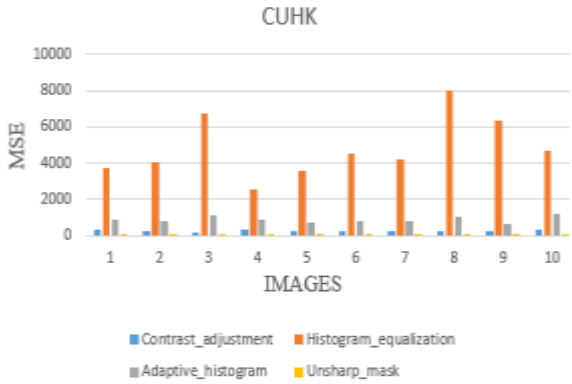

Fig.5: Plot for analyzing MSE values with CUHK dataset sketches

The above fig. 5 represents that MSE values are low for the sketches corresponding to Unsharp Masking and high for the Histogram equalization image enhancement technique.

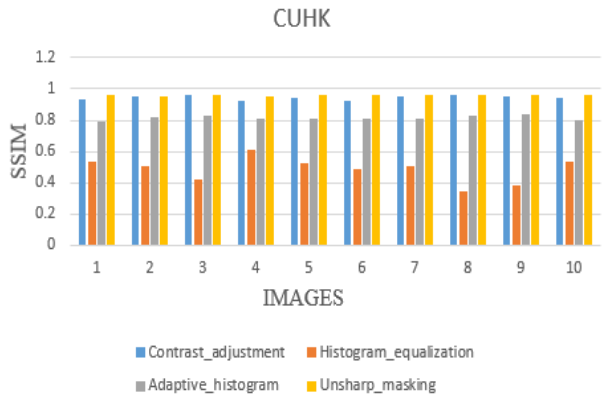

Fig. 6: Plot for analyzing SSIM values with CUHK dataset sketches

The above fig. 6 represents that SSIM values are high for the sketches corresponding to Unsharp Masking and low for the Histogram equalization image enhancement technique.

Thus the overall analysis results that Unsharp masking technique is better method used for image enhancement.

PRIP-HDC DATASET

TABLE II: Comparison of Quality Metrics for PRIP_HDC Dataset

Image Enhancement Techniques (PRIP_HDC dataset)	Quality Metrics		
	PSNR	MSE	SSIM
Contrast adjustment/stretching	18.25323	1045.98714	0.90573
Histogram Equalization	8.31581	10371.59159	0.52154
Adaptive Histogram Equalization	17.94376	1085.99299	0.83384
Unsharp Masking	32.41604	40.33213	0.97238

The above Table II illustrates the different quality metrics along with their average values for various image enhancement techniques for PRIP-HDC dataset.

The below shown graphs represents the plot for PSNR, MSE and SSIM values.

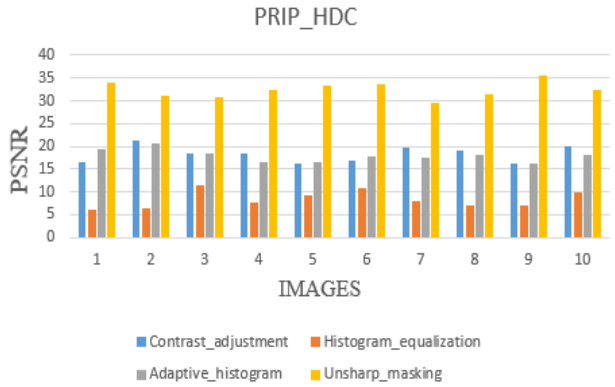

Fig. 7: Plot for analyzing PSNR values with PRIP-HDC dataset sketches

The above fig. 7 represents that PSNR values are high for the sketches corresponding to Unsharp Masking and low for the Histogram equalization image enhancement technique.

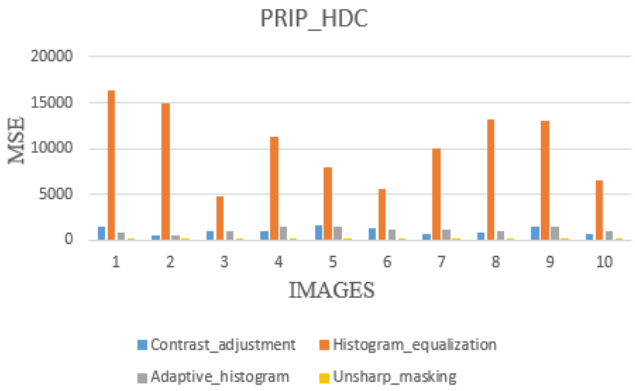

Fig. 8:: Plot for analyzing MSE values with PRIP-HDC dataset sketches

The above fig. 8 represents that MSE values are low for the sketches corresponding to Unsharp Masking and high for the Histogram equalization image enhancement technique.

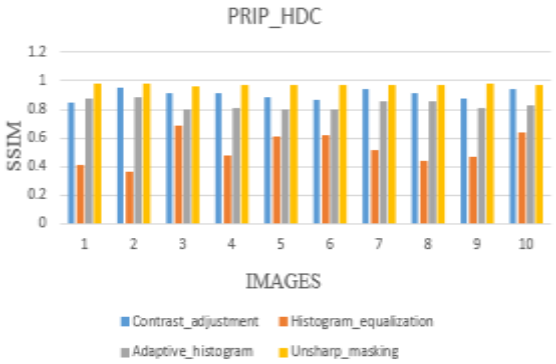

Fig. 9: Plot for analyzing SSIM values with PRIP-HDC dataset sketches

The above fig. 9 represents that SSIM values are high for the sketches corresponding to Unsharp Masking and contrast adjustment, low for the Histogram equalization image enhancement technique.

Thus the overall analysis results that Unsharp masking technique is better method used for image enhancement.

Time Complexity

The estimation or measures of time taken for running an algorithm is said to be Computational complexity.

TABLE III: Time Complexity for Different datasets

Dataset	Elapsed Time (sec)			
	Contrast Adjustment	HE	AHE	Unsharp Masking
CUHK	0.6077	0.6400	0.8726	0.5847
PRIP_HDC	0.6126	0.5609	0.7209	0.5815

The above Table III represents the time complexity calculated for CUHK and PRIP-HDC datasets with different enhancement techniques.

5. Conclusion

Using viewed sketches and composite sketches as a source of input, we have performed the comparative analysis between different image enhancement techniques in order to find the better image enhancement technique for sketches. Two different datasets are used for measuring the quality metrics. Quality metrics are measured using the three main generally used assessment methods such as PSNR, SSIM and MSE along with their computational time factor. It is noted that SSIM outperforms the PSNR and MSE in terms of measuring the quality of sketches. Experimental results shows that contrast adjustment and unsharp masking techniques using SSIM provide a better result.

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