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An Improved Image Enhancement Approach With HSI Color Fuzzy Decision Modelling

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Abstract— The image enhancement is the most prominent topic among researchers to introduce more amendments in this domain. The image enhancement covers a large number of techniques, mechanisms and ways to enhance the image. The contrast enhancement or to improve the brightness of the image is one of the way to improve the quality of the image. This study develops a novel approach for image contrast enhancement by considering HSI color model to extract the Hue, Saturation and Intensity of the image. Then the fuzzy inference system is applied to improve the intensity of the image pixels. The simulation is done by considering a set of four different images. The performance of the proposed work is evaluated in the terms of Detail Variance and Background Variance. The proposed work is compared with the traditional GLE (Global Local Image Enhancement), Enhanced AHE (Adaptive Histogram Equalization) and Original Image**.** The simulation results delineates that the proposed work performs outstanding in comparison to the tradition GLE, Enhanced AHE and original image.

Keywords— Image Enhancement, Contrast Enhancement, Color Model, HIS Model, Fuzzy Inference Model.

I. INTRODUCTION

The contrast enhancement is the most important phase of the image processing [1]. The difference of brightness between the object and the background is enhanced in the process of contrast enhancement. The contrast enhancement is done in two consecutive ways. In the first way, the difference of the brightness across the image dynamic range is enhances and this way is called contrast stretch. After contrast stretch the difference of the brightness between the dark, grey and bright region [2] is enhanced this is termed as tonal enhancement. In image enhancement, the contrast plays a very important role in determining the details in the image. To enhance the contrast of the image, the characteristics of the image are enhanced. Images are sometimes unclear/dark [3], these kinds of images are made brighter and clearer by enhancement of contrast of these images. The contrast enhancement makes images much more clear and details from the images can easily obtained. This technique of image enhancement is widely used in medical image enhancement where even minute detail is very crucial [4]. X-Ray defines the skeletal structure of the body. X-Ray images are used to determine the fractures in the bon but these images are very low in contrast. Contrast enhancement extracts the details [5] from the images and amplifies them so that every minute detail will becomes easily visible.

This study is organized in 6 different sections. In first section the introduction is given to the contrast enhancement, second section explains problem or drawback of proposed work that act as a motivation for the proposed work. In 3rd section the proposed work is defined briefly along with the flowchart and mathematical implementation. In 4th section the results are represented that are obtained after implementing the proposed work in MATLAB. In last section the study concludes briefly on the basis of the obtained results and comparison of proposed work.

II. PROBLEM FORMULATION

The traditional contrast enhancement technique for enhancing the image quality implements the concept of contrast enhancement using the global mean of entire image and local mean of 3x3 sub images. Local mean filter is used to smooth the image by taking the mean value of the pixels surrounding the centre pixel within the image. But this hybridization has not proved as much effective because global mean equalization uses the histogram information of the entire input image for its transformation function. It fails to adapt with the features of local brightness of input image. GHE remaps the gray levels in such a way that the contrast stretching becomes limited in some dominating gray levels which have larger image histogram components and causes contrast loss for small ones. The local histogram equalization also faces the issues like it is quite high computational cost and sometimes it causes over-enhancement in some portions of the image. It also enhances the noises in the input along with the image features. Thus it is not mandatory that the GHE is capable to overcome the failures of LHE and vice versa. Thus there is a need to develop an enhancement mechanism by using advanced mechanism which can enhance the image by preserving intensity of the image.

III. PROPOSED WORK

The above section defines that the traditional contrast enhancement mechanism implements the collaboration of local and global equalization technique but still it was less efficient and LHE and GHE has their own limitations. Thus the present study implements the HSI model along with fuzzy based image enhancement mechanism. The hue and intensity domain of HSI is passed to fuzzy logics and after that the fuzzy based hue and intensity is combined with saturation of and thus the finalized improved and enhanced image is received. The fringe of the proposed work is that it overcomes the backlog of both global and local histogram equalization and also it incurs less computation cost. Step 1: First step is to select an input image for further processing. The input image can be a RGB or grayscale image.

Step 2: After inserting the image, next step is to convert the input image to HIS format. Following formulation is used for conversion. First of all the RGB normalization is done to convert the image.

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B} \ldots\ldots (1.1)$$

Following normalized HIS component is observed:

$$h = \left\{ \frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-g)(g-b)]^{1/2}} \right\} h \in [0,\pi] for\ b \leq g \ldots (1.2)$$

$$h = 2\pi - cos^{-1} \left\{ \frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-g)(g-b)]^{1/2}} \right\} h \in [0,2\pi] for\ b > g \ldots (1.3)$$

$$s = 1 - 3.min(r,g,b); s \in [0,1] \ldots. (1.4)$$

$$i = \frac{R+G+B}{3.255} \quad i \in [0,1] \ldots\ldots. (1.5)$$

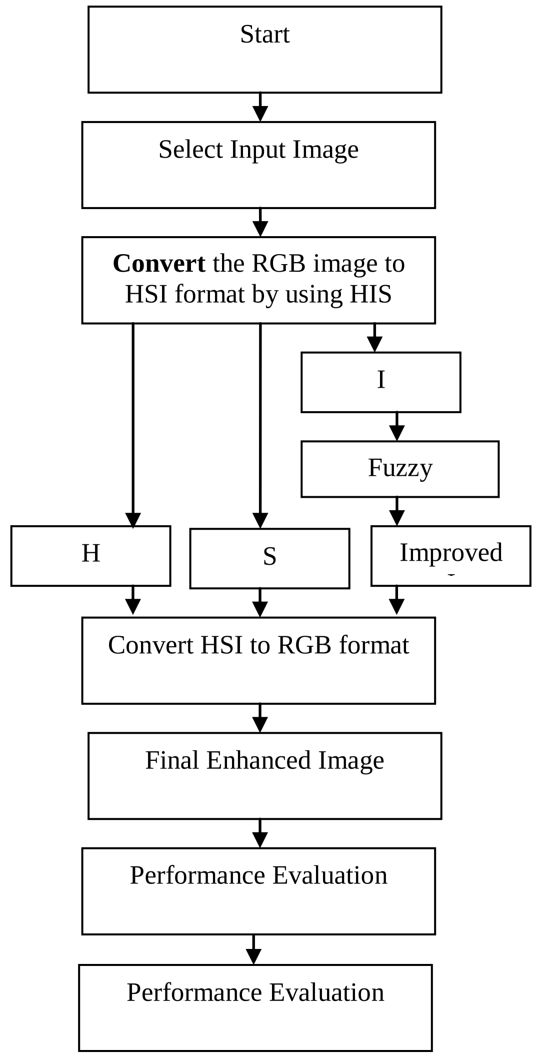


Figure 1 Framework of proposed work

Step 3: Apply Fuzzy Equalizer to the intensity to obtain the new value of intensity.

Step 4: Convert image of HIS format to RGB format by applying following formulation:

$$h = H.{}^{\pi}/_{180} \ldots. (1.6)$$

$$s = {}^{S}/_{100} \ldots\ldots (1.7)$$

$$i = I/255 \ldots.. (1.8)$$

$$x = i.(1-s) \ldots\ldots (1.9)$$

$$y = i.\left[1 + \frac{s.cos(h)}{cos(\frac{\pi}{3} - h)}\right] \ldots.. (1.10)$$

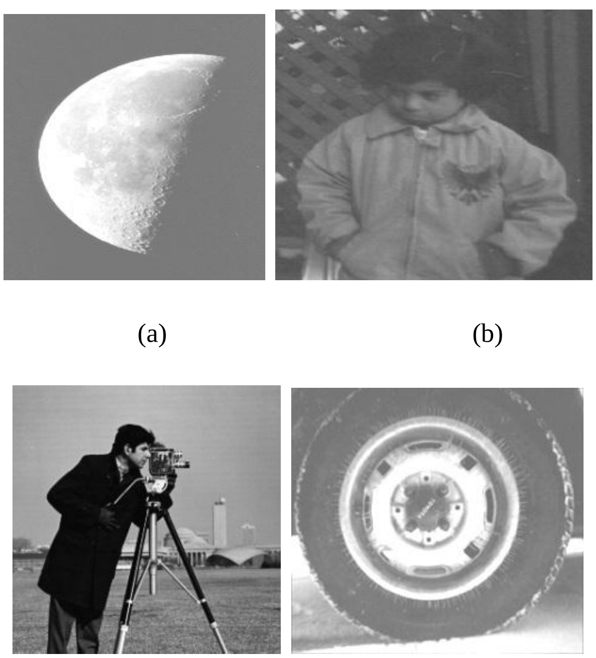
$$z = 3i - (x+y); \ldots\ldots (1.11)$$

$$When\ h < \frac{2\pi}{3}, b = x, r = y, g = z\ and\ when\ \frac{2\pi}{3} \leq h < \frac{4\pi}{3}, h = h - \frac{2\pi}{3}\ and\ r = x, g = y, b = z\ and\ when \frac{4\pi}{3}, h = h - \frac{4\pi}{3}, g = x, b = y, r = z$$

Step 5: Final Enhanced Image is obtained.
Step 6: Perform Performance Evaluation by measuring performance parameters.

IV. RESULTS

This study performs the contrast enhancement to increase the quality of the image. For the purpose of contrast enhancement, the concept of HSI model and fuzzy inference system is applied. This section depicts the results that are obtained after implementing the proposed work in MATLAB. For the purpose of image contrast enhancement, the image is an important part. Thus, the first step is to enter the image to the proposed system. For this purpose three different images are used and defined as follows in figure 2.



(a) (b)

(c) (d)

Figure 2 Sample Images (a) Moon (b) Pout (c) Cameraman (d) Tier

In proposed work, the image of pout is considered as an input image. The image in figure 3 depicts the input image. After entering the image, the HIS image of input image is shown in figure 4. The HSI conversion is fully explained in methodology section of this work.

Figure 3 Original Input image

Figure 4 HSI Converted Image

After converting the format of the image the fuzzy inference system is designed to optimize the intensity of the image.

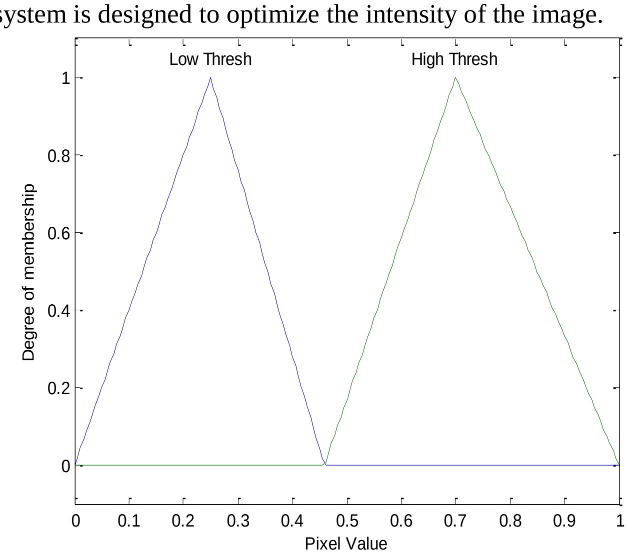


Figure 5 Input Membership Function

The proposed fuzzy inference system takes an input i.e. Pixel value. The graph in figure 5 depicts the input membership function where x axis represents the pixel value that ranges from 0 to 1. The y axis in graph shows the degree of membership function that ranges from 0 to 1.

The graph in figure 6 depicts the output membership function of proposed fuzzy inference system.

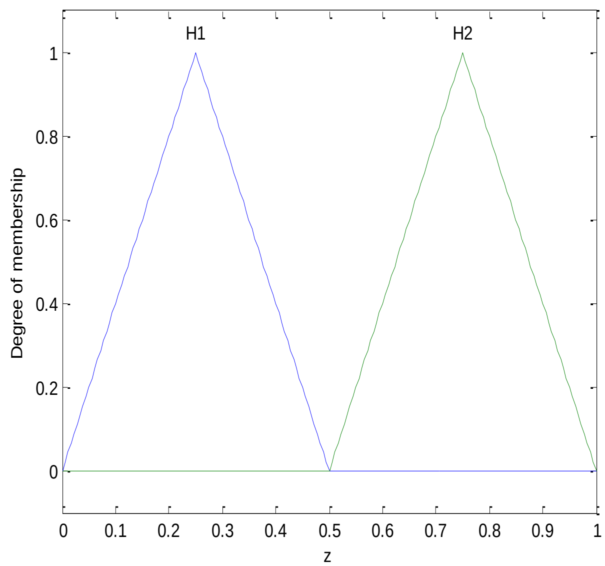


Figure 6 Output memberships Function

The proposed fuzzy inference system is presented in figure 7. As per the observations from figure, the FIS implements MAMDANI fuzzy system and generates an output membership function on the basis of a single input membership function. To obtain the output, the system implements the a set rules (2 rules)

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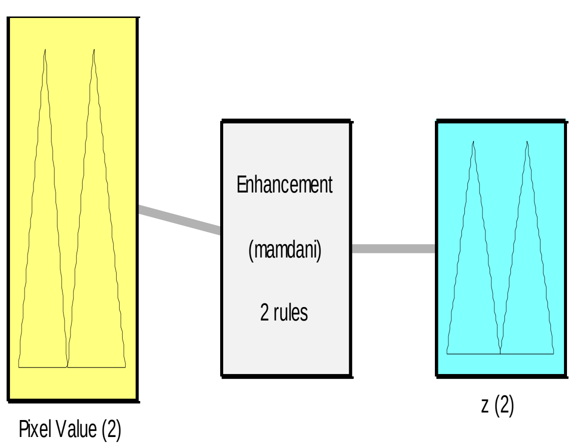

Figure 7 Proposed Fuzzy Inference Systems

Figure 8 shows the image that is obtained after implementing the proposed FIS.

Figure 8 Image generated by Fuzzy Inference System

The final contrast enhanced image is shown in figure 9.

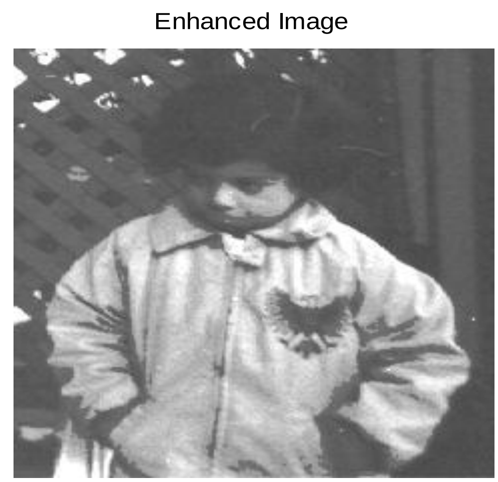

Figure 9 Final Enhanced image

After receiving the final enhanced image, the performance of the proposed work is evaluated in the following terms:

1. Detail Variance (DV)
2. Background Variance (BV)

DV and BV is a performance matrix that is used to evaluate the level of enhancement in an image. This is evaluated by using local variance of n adjacent pixels from all images. To evaluate DV and BV, first of all, a variance matrix is created. Then each pixel is divided into two classes and the variance of each pixel is compared with the defined threshold value. If the variance is greater than the threshold value then the pixel is considered to be related with the image foreground else it is related to the image background. After classifying the pixel, the mean variance of belonging pixels is calculated and termed as DV and BV. It is necessary that the value of DV and BV should always high.

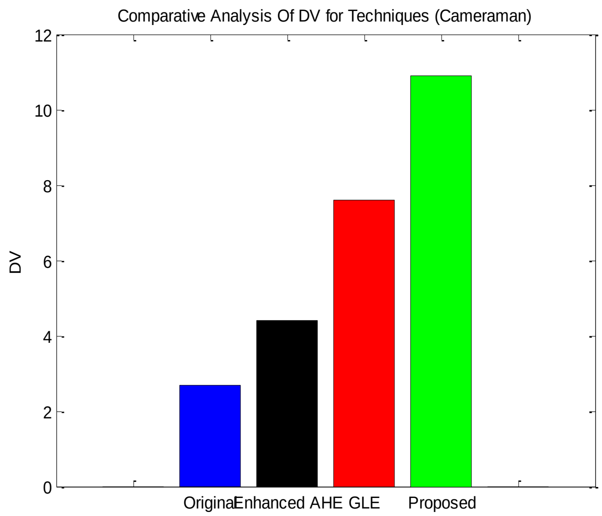

Figure 10 Comparison Analysis of DV for Cameraman

The graph in figure 10 shows the comparison of proposed and traditional contrast enhancement technique on the basis of DV. The comparison is done by considering the image of cameraman. The bar in green color represents the DV of proposed contrast enhancement technique which quite high and better than the DV of other techniques and original image. The table 1 shows the observations of graph.

Table 1 Comparison for DV (Cameraman Image)

Technique	**DV**
Proposed Work	10.9
GLE (Global Local Image Enhancement)	7.6
Enhanced AHE (Adaptive Histogram Equalization)	4.4
Original Image	2.7

The graph in figure 11 shows the comparison of BV for image of cameraman. The comparison is done among proposed, GLE, Enhanced AHE and original image. The x axis in graph calibrates the data in terms of various techniques and y axis describes the value for BV. The table 2 shows the facts and figures that are obtained after analyzing the following comparison graph.

Table 2 Comparison for BV (Cameraman Image)

Technique	**BV**
Proposed Work	10.9
GLE (Global Local Image Enhancement)	6.4
Enhanced AHE (Adaptive Histogram Equalization)	4.1
Original Image	2

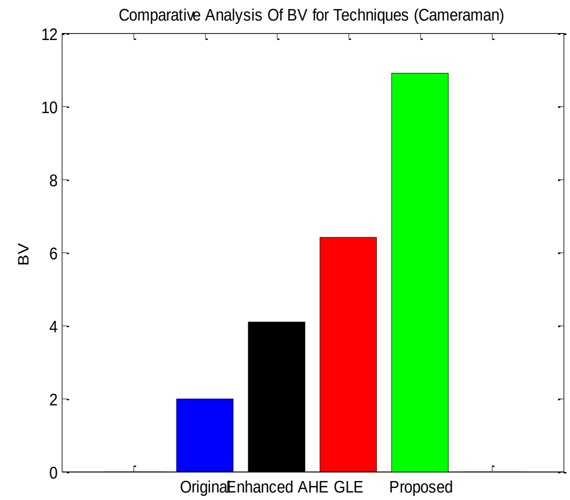

Figure 11 Comparison Analysis of BV for Cameraman

The graph in figure 12 shows the DV comparison for image of pout. The comparison table explains that proposed work outperforms the other techniques. As the DV of pout in proposed work is 6 whereas the DV for GLE is 4.1, enhanced AHE is 4 and for original image it is 2.7. the table 3 depicts the figures on the basis of comparison graph.

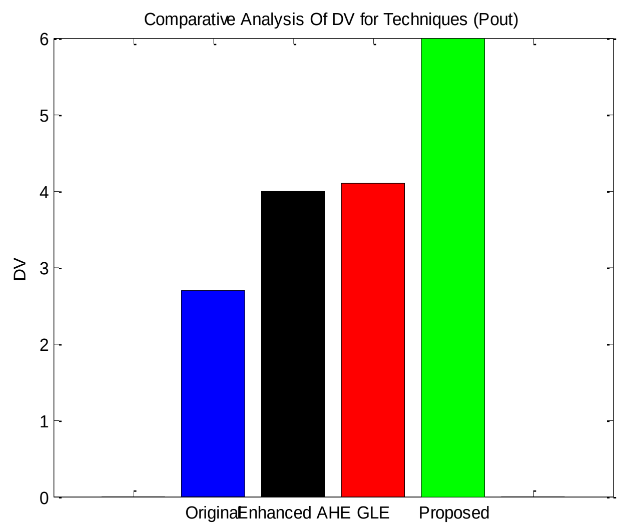

Figure 12 Comparison Analysis of DV for Pout.

Table 3 Comparison for DV (Pout Image)

Technique	**DV**
Proposed Work	6
GLE (Global Local Image Enhancement)	4.1
Enhanced AHE (Adaptive Histogram Equalization)	4
Original Image	2.7

The comparison for BV of pout image is presented in figure 13. Similarly, table 5.4 shows the values corresponding to the proposed work, GLE, Enhanced AHE and original image.

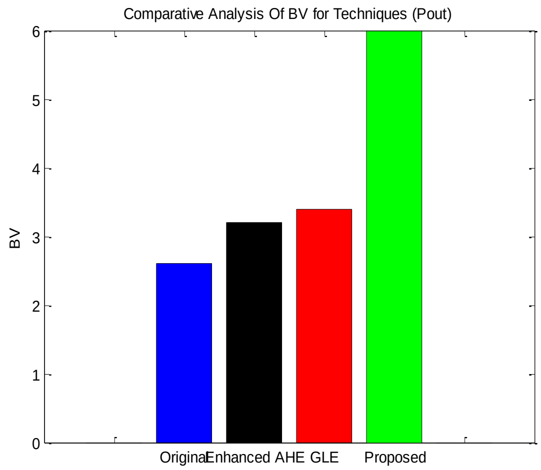

Figure 13 Comparison Analysis of BV for Pout.

Table 4 Comparison for BV (Pout Image)

Technique	BV
Proposed Work	5.99
GLE (Global Local Image Enhancement)	3.4
Enhanced AHE (Adaptive Histogram Equalization)	3.2
Original Image	2.6

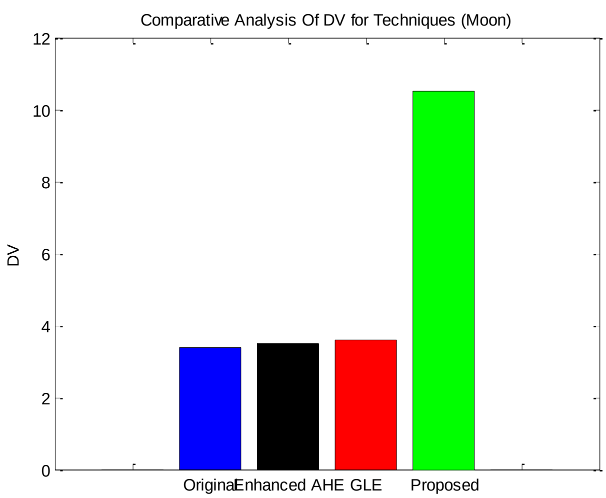

Figure 14 Comparison Analysis of DV for Moon.

The DV and BV for image of moon is shown in figure 14 and 15. The x axis in both graphs mentions the techniques and these techniques are depicted with different colors. The y axis represents the value for DV and BV for corresponding image. The range of DV and BV lies between 0 and 12.

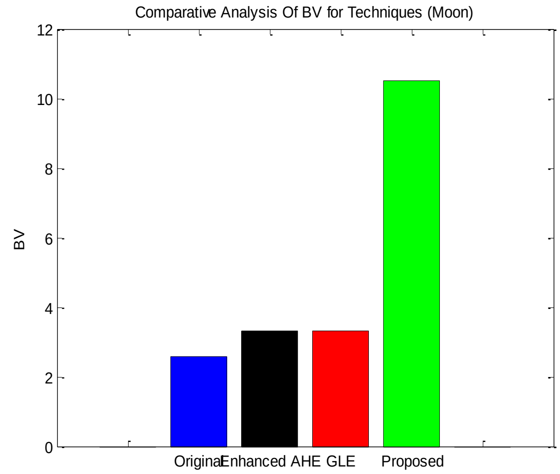

Figure 15 Comparison Analysis of BV for Moon.

The corresponding observed values are shown in table 5 and 6., On the basis of the tables it is concluded that the DV and BV of proposed work is high for image of moon in comparison to other techniques and original image.

Table 5 Comparison for DV (Moon Image)

Technique	DV
Proposed Work	10.5
GLE (Global Local Image Enhancement)	3.6
Enhanced AHE (Adaptive Histogram Equalization)	3.5
Original Image	3.4

Table 6 Comparison for BV (Moon Image)

Technique	BV
Proposed Work	10.5
GLE (Global Local Image Enhancement)	3.3
Enhanced AHE (Adaptive Histogram Equalization)	3.3
Original Image	2.59

The Detail Variance and Background Variance for image tier are shown in graph 16 and 17. The DV and BV for image of tier that observed in proposed work is compared with the DV and BV of same image in GLE, enhanced AHE and original image. The proposed work outperforms 5the in both cases with respect to the rest of the traditional techniques.

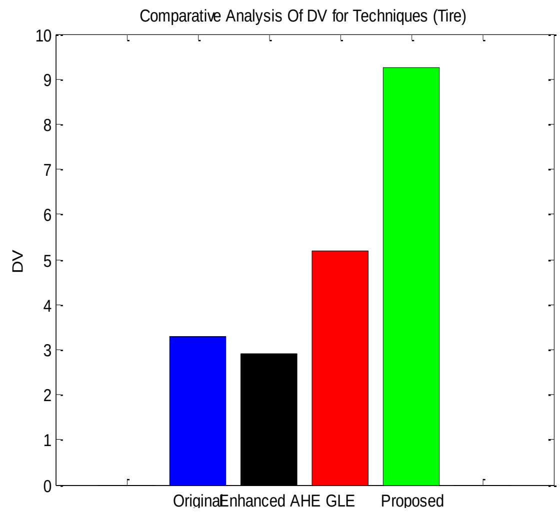

Figure 16 Comparison Analysis of DV for Tier.

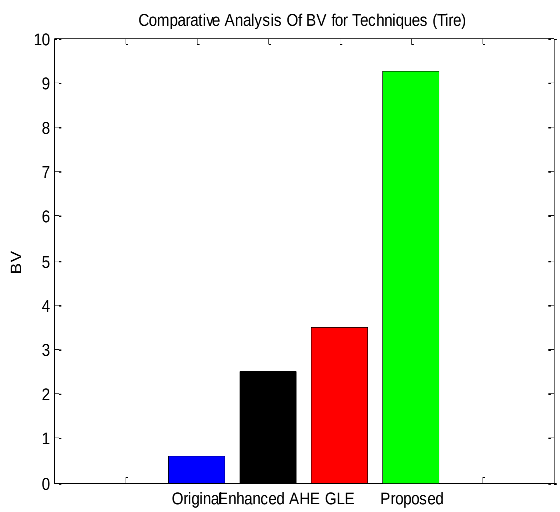

Figure 17 Comparison Analysis of BV for Tier.

The table 7 and 8 unveil the values for DV and BV that are observed from graph 16 and 17. The tables comprised of vales corresponding to the proposed work, GLE, enhanced AHE and original image. In all cases the DV and BV of proposed work is better than the other mechanisms.

Table 7 Comparison for BV (Tier Image)

Technique	**BV**
Proposed Work	9.26
GLE (Global Local Image Enhancement)	3.5
Enhanced AHE (Adaptive Histogram Equalization)	2.5
Original Image	0.6

Table 8 Comparison for DV (Tier Image)

Technique	**DV**
Proposed Work	9.26
GLE (Global Local Image Enhancement)	5.2
Enhanced AHE (Adaptive Histogram Equalization)	2.9
Original Image	3.3

V. CONCLUSION

The image enhancement is such a vast domain itself and covers a large number of techniques under single umbrella. The image enhancement can be done in multiple ways such as by enhancing the contrast, brightness, by dividing the image on the basis of objects including in it i.e. image segmentation, by fusing two inefficient images to create an efficient once etc. Contrast enhancements play a vital role to enhance the quality of an image in order to increase the productivity of the image. There are large number of mechanisms are available in research field to enhance the contrast of an image. This study develops a contrast enhancement technique by utilizing the HSI image format and fuzzy inference system. The HIS model is used to extract the hue, saturation and intensity of the image and then the Fuzzy inference system is applied to the observed Intensity values to optimize it. Then in this way, more enhanced image with improved contrast is obtained. The performance of the proposed work is evaluated by using two different performance matrices i.e. DV and BV. It has been concluded that the propped work outperforms the traditional GLE, Enhanced AHE and Original image. The performance evaluation is done by considering 4 different images.

The present work implements the single colour model i.e. HIS model to improve the contrast of the image. Wherever, in future the present system can be enhanced by implementing multi color model such as YCbCr. Along with this the different hybridization of contrast enhancement techniques are also possible.

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