Enhancement of Dental Digital X-Ray Images based On the Image Quality

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Abstract: Medical Image Enhancement has made revolution in medical field, in improving the image quality helping doctors in their analysis. Among the various modalities available, the Digital X-rays have been extensively utilized in the medical world of imaging, especially in Dentistry, as it is reliable and affordable. The output scan pictures are examined by practitioners for scrutiny and clarification of tiny setbacks. A technology which is automated with the help of computers to examine the X-Ray images would be of great help to practitioners in their diagnosis. Enhancing the visual quality of the image becomes the prerequisite for such an automation process. The image quality being a subjective measure, the choice of the methods used for enhancement depends on the image under concern and the related application. This work aims at developing a system that automates the process of image enhancement using methods like Histogram Equalization(HE), Gamma Correction(GC),and Log Transform(LT). The decision of the enhancement parameters and the method used is chosen, with the help of the image statistics (like mean, variance, and standard deviation). This proposed system also ranks the algorithms in the order of their visual quality and thus the best possible enhanced output image can be used for further processing. Such an approach would give the practitioners flexibility in choosing the enhanced output of their choice.

Keywords: Image Enhancement, Dental Images, X-Ray Images, Log Transform, Histogram Equalization, Gamma Correction and Entropy.

1. INTRODUCTION

Image enhancement has a great influence in vision applications and also takes a major role in it. The main objective of enhancement is to elevate the structural aspect of an object without causing any downgrade in the input image and to improve the visual qualities of the image in order to make it appropriate for a given application. The aim of enhancement is to improve the perception of the details and information in the images [3].It improves the view of the image thereby providing a processed input for further processing. In general, in case of images an enhancement is performed to improve its contrast and brightness, so that the objects of interest are clearly and distinctly visible from the background.

There are different modalities in medical imaging such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), X-ray, PET-CT, and Biomarkers etc. Among these, Digital X-rays have been extensively used for image acquisition in the field of medical imaging. This work focuses on the Dental X-Ray images, which are used by dentists for the analysis of the Tooth structure and anomalies present. Human clarification is predominantly based on the knowledge and the experience of the person. The acquired image quality depends on various factors like the imaging sensors, lighting present, noise and the area/ object being imaged [5]. Making analysis from an image that has poor visual quality is often a difficult and time consuming task. Additionally, if there are a large number of X-rays to be examined, as in case of structure analysis, then the process may be time consuming. In all such cases an automated tool that could help in the analysis process would be very useful. Such automation requires segmentation, feature extraction and recognition of the regions in the image under consideration. For these processes to be accurate one aspect is the quality of the input image. To ensure that the image is of good quality, an analysis of the image statistics, like mean and standard deviation, which gives the details of the brightness and contrast of the input image, would be useful. In this work one such approach for automating the enhancement process by considering the image statistics has been carried out. The organization of the paper is as follows: Section 2 discusses the review of literature in enhancement of dental X-Ray images. The proposed enhancement system has been elaborated in section 3 and the results and analysis are discussed in section 4. Section 5 gives the conclusion driven from this work.

2. BACKGROUND STUDY

Image Enhancement has been a topic of research in the field of image processing. A huge amount of literature is available pertaining to this in general. But with respect to enhancement of Digital X-Ray images and Dental image especially, the availability of literature is scarce. Hence in this work focus has been given to enhancement of dental x-ray images. This section discusses the existing literature available for enhancing such x-ray images.

Yeong-Taeg Kim, [1] conducted a study on contrast enhancement using Bi-Histogram equalization. This work focused on overcoming the drawbacks of Histogram Equalization. The input image is decomposed into sub images. Histogram Equalization is performed for the sub images. The equalized images are bounded in such a way that they occur around the mean. Foisal et al. [2] has discussed a method for Image Enhancement Based on Non-Linear Technique. The method uses Logarithmic Transform Coefficient Histogram Matching for enhancing images with dark shadows which is caused due to the restricted dynamic range. Fan et al. [3] has conducted a study on improved image contrast enhancement in multiple-peak images. The study is based on histogram equalization. This study put forth a new technique which works well for the images with multiple peaks and this mainly focuses on the enrichment of the contrast of the given input image. M. Sundaram et al. [4] has studied the histogram based contrast enhancement for mammogram images. This is used to detect micro calcification of mammograms. Histogram Modified Contrast Limited Adaptive Histogram Equalization (HM-CLAHE) is used which controls the level of enhancement in compared with histogram equalization. G. N. Sarage and Dr Sagar Jambhorkar, [5] studied the enhancement of chest x-ray images. Filtering techniques like mean and median filtering are applied to improve the quality of the images. These filters reduce the noise in the given image. D Cheng and Yingtao Zhang, [6] has performed a study in order to detect Over-Enhancement of images. Over – enhancement causes edge-loss, changes the texture of the image and makes the image appear unrealistic. The cause for over-enrichment is analysed and the over-enriched portions are identified accurately in this work. The level of over-enhancement is assessed using quantitative methods. Ikhsan et al., [7] has discussed a new method for contrast enhancement of retinal images that would help in diabetes screening system. In their work three techniques for improving image contrast namely, Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE) and Gamma Correction (GC) had been used. Ritika and Sandeep Kaur, [8] studied the contrast enhancement techniques for images and proposed a technique based on mathematical morphology analysis to enhance image contrast. Here HE and CLAHE have been analysed to reduce the low contrast in the images. In CLAHE, local enhancement of the image is done without amplifying the unnecessary noises. Datta et al. [9] conducted a study to identify a contrast enhancement method of retinal images in diabetic screening system. This work enhances the image using various techniques and ensures s the brightness and quality of the image is preserved. Performance parameters like SSIM (Structure Similarity Index Measurement) and AAMBE (Average Absolute Mean Brightness Error) are applied to preserve quality of the image while enhancing. Of late the use of Partial Differential Equations (PDE) for enhancement and restoration of medical images [10] is gaining prominence. Huang et al. [11] studied the efficient contrast enhancement. It was achieved by adaptive gamma correction with weighting distribution. It provides image enhancement by modifying the histograms. Murahira and Akira Taguchi

[12] explain a method for contrast enhancement that analyses grey-levels in the image using a histogram and compares it with conventional histogram. Abdullah-Al-Wadud et al. [13] studied contrast enhancement using dynamic histogram equalization (DHE). This divides the image using local minima and equalization is performed on individual portions thereby reducing the side effects of conventional method. Stark [14] worked on image contrast enhancement by generalising the histogram equalization. It is performed using various forms of cumulative functions. Hadhoud, [15] studied enhancement of images using adaptive filters and Homomorphic processing. Both low and high adaptive filters are used and they are in combined in a domain with homomorphism and performs contrast enhancement. Debashis Sen et al. [16] performed a study on contrast enhancement by automatic exact histogram specification. It performs quantitative evaluation of the results. Mehdizadeh and Dolatyer [17] have analysed the use of Adaptive HE on dental X-Rays. Ahmad et. Al., [18] have in their work compared different ways of Equalizing the Histogram for enhancing the quality of dental X-Ray images. Turgay Celik et.al. [19] proposed an adaptive algorithm for image equalization which enhances the contrast of the given image automatically. They used Gaussian mixture model and analysed the gray level distribution of the image.

2.1 Findings and Observations:

Very few researchers have ventured into the enhancement and analysis of dental X-Ray images. In most of the work existing for enhancing the X-Ray image quality, the Histogram Equalization method has been adopted. This method is found to give good results when modelled adaptively. For enhancing the contrast and brightness of images methods like Log-Transform and Gamma Correction have also been used. From the nature of these methods, it is obvious that they can also be used for enhancing dental images. It would be more effective if the selection of the enhancement method is made based on the quality statistics of the input image. In this regard there is scarcity of literature.

3. PROPOSED SYSTEM

To enhance the visual quality of the Dental X-ray image the contrast and the brightness (visual quality) has been enhanced in this work by taking into account the input image statistics. Three algorithms namely Histogram Equalization (HE), Gamma Correction (GC) and Log Transform (LT) have been analyzed for 40 dental X-Ray images. The Image statistics used are the mean, variance and standard deviation. The algorithm is ranked based on the statistics obtained.

The aim here is to choose an appropriate enhancement algorithm for the given image and also to decide the optimum value for enhancement parameters from the statistics of the image in case of Gamma correction. This method improves the quality of the input image based on the amount of enhancement needed for that image. Figure 1 shows the overall system design.

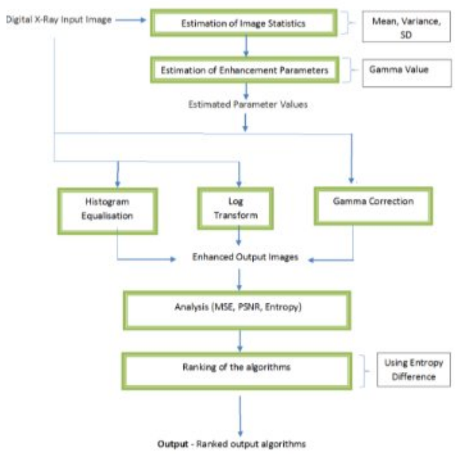


Figure. 1. Shows the system architecture representing the flow of input data into the system and output from the system.

The input image is enhanced using the specified algorithms. For Gamma Correction the value for the Gamma (ϒ) parameter is decided based on the mean and standard deviation of the input image.

If input image has poor contrast/brightness the Gamma > 1

If input image has high contrast/ brightness, then Gamma <1

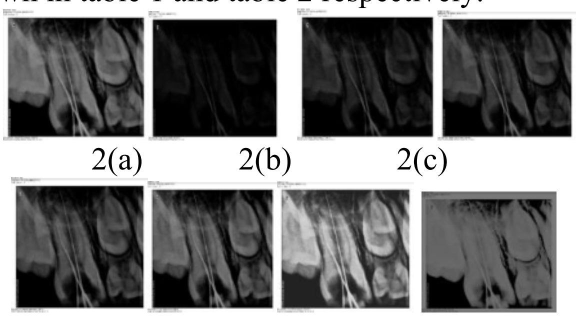
Else If image is of Good Contrast then Gamma = 1 (No enhancement is needed).

These statistics are inferred from the image histogram. The mean tells about the image brightness and the standard deviation gives the information regarding the image contrast. The enhanced output images obtained using the three algorithms are then compared for finding out the best enhanced output, by analysing the entropy of the input and the output images. The results obtained and the ranking procedure is discussed in detail the next session.

4. RESULTS AND ANALYSIS

The results obtained for a sample data set image is shown in figure 2. For the 40 images considered the Gamma correction is performed for gamma values of 0.3, 0.45, 0.6, 0.75 and 0.9.

The statistics obtained from the input and output images of figure 2 are shown in table 1 and table 2 respectively.



2(a) 2(b) 2(c) 2(d)

2(e) 2(f) 2(g) 2(h)

Figure 2: (a) Input image1, (b) Output from Gamma Correction with gamma value 0.3 (GC 0.3), (c) Output from GC 0.45, (d) Output from GC 0.6, (e)Output from GC 0.75, (f) Output from GC 0.9, (g) Output from HE, (h) Output from LT.

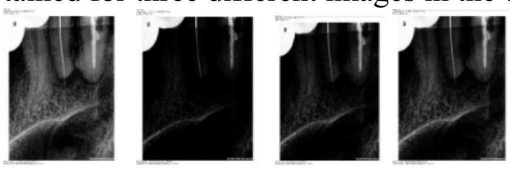
Table. 1. Image Statistics of the Input image given in figure 2(a).

No of rows	No of columns	Mean	Variance	Standard Deviation	Entropy
3300	2550	239.3891	50.4773	7.1047	6.2115

Table. 2. Image statistics for the output images obtained (2(b) – 2(h)) using HE, LT and GC.

	GC_0.3	GC_0.45	GC_0.6	GC_0.75	Gc_0.9	LT	HE
MEAN	247.1122	243.9598	241.9565	240.6961	239.8948	245.6629	236.9495
VARIANCE	37.4095	43.3556	46.6463	48.5363	49.7119	40.0432	53.4065
STANDARD DEVIATION	6.1163	6.5845	6.8298	6.9668	7.0507	6.3279	7.3079
ENTROPY	4.0117	5.0793	5.6072	5.9188	6.0979	4.9952	6.1031

Figure 3, 4 and 5 shows the input and the corresponding outputs obtained for three different images in the data set considered.



3(a) 3(b) 3 (c) 3(d)

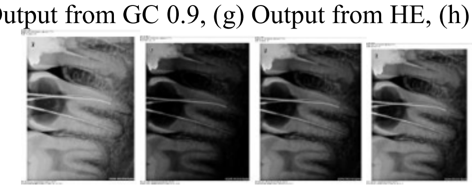
3(e) 3(f) 3(g) 3(h)

Figure 3: (a) Input image2, (b) Output from Gamma Correction with gamma value 0.3 (GC 0.3), (c) Output from GC 0.45, (d) Output from GC 0.6, (e) Output from GC 0.75, (f) Output from GC 0.9, (g) Output from HE, (h) Output from LT.

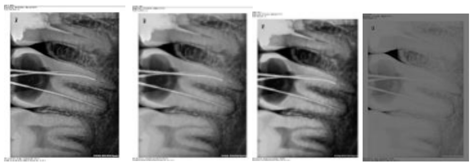
4 (a) 4 (b) 4(c) 4(d)

4(e) 4 (f) 4(g) 4(h)

Figure 4: (a) Input image3, (b) Output from Gamma Correction with gamma value 0.3 (GC 0.3), (c) Output from GC 0.45, (d) Output from GC 0.6, (e) Output from GC 0.75, (f) Output from GC 0.9, (g) Output from HE, (h) Output from LT.



5 (a) 5 (b) 5(c) 5(d)



5(e) 5 (f) 5(g) 5(h)

Figure 5: (a) Input image4, (b) Output from Gamma Correction with gamma value 0.3 (GC 0.3), (c) Output from GC 0.45, (d) Output from GC 0.6, (e) Output from GC 0.75, (f) Output from GC 0.9, (g) Output from HE, (h) Output from LT.

The entropy of the input image is compared with the entropy of output obtained from each algorithm. The algorithms are then ranked based on the entropy differene between the input and the output image. The algorithm with lower entropy difference has been ranked as the best , followed by the rest in increasing order of the entropy differences and the results are tabulated in table 3.

Table. 3. Ranking of the algorithms for the input images in figures2(a), 3(a), 4(a) and 5(a) Based on Entropy Difference Value (EDV).

	Ranking for Image in figure 2(a)		Ranking for image in figure3(a)		Ranking for image in figure4(a)		Ranking for image in figure5(a)	
Rank	Algorithm	EDV	Algorithm	EDV	Algorithm	EDV	Algorithm	EDV
1	**HE**	0.1084	**GC_0.9**	0.1364	**GC_0.9**	0.1066	**GC_0.9**	0.03183
2	GC_0.9	0.1136	HE	0.1790	GC_0.75	0.3037	GC_0.75	0.1003
3	GC_0.75	0.2927	GC_0.75	0.3874	HE	0.3086	HE	0.1695
4	GC_0.6	0.6043	GC_0.6	0.7923	GC_0.6	0.6188	GC_0.6	0.2167
5	GC_0.45	1.1323	LT	1.3004	GC_0.45	1.1883	GC_0.45	0.4430
6	LT	1.2164	GC_0.45	1.5027	LT	1.5928	GC_0.3	1.0679
7	GC_0.3	2.1997	GC_0.3	2.8181	GC_0.3	2.2957	LT	1.9934

INFERENCE:

- Visual observation of the results obtained for the images also reveals that for the input image in figure 2(a) the Histogram Equalization (HE) gave the best result. Similarly, for the images in figures 3, 4 and 5 the Gamma Correction with gamma value of 0.9 was found to be better than the other methods.
- The behaviour of the algorithm changes with the quality of the input image considered.

For all the 40 images in the data set the entropy difference have been calculated. To assess the behaviour of the algorithm on the different types of images in the data set considered the standard deviation of the entropy difference for the algorithms has been computed. The algorithm for which the deviation is less can be considered as the one that is giving the similar enhanced result (better enhanced images) for most of the images in the data set and hence can be taken as the best algorithm for the given data set. Table 4 shows entropy difference values obtained for few images and the Scatter Plot for the entire data set is shown in figure 6.

Table.4. shows the entropy difference of the 40 images in the data set and the overall standard deviation.

Data Set	Methodology Used						
	GC_0.3	GC_0.45	GC 0.6	GC_0.75	GC_0.9	LT	HE
1	2.2	1.132	0.604	0.293	0.114	1.216	0.108
2	2.296	1.188	0.619	0.304	0.107	1.593	0.309
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39	1.036	0.609	0.415	0.23	0.097	1.89	0.256
40	0.614	0.247	0.124	0.055	0.021	2.163	0.216
SD	0.713	0.394	0.216	0.11	0.041	0.456	0.056

From the Table.4 the minimum standard deviation of the entropies of all the 40 images from the data set is 0.041 corresponding to Gamma Correction with gamma value 0.9(GC_0.9).

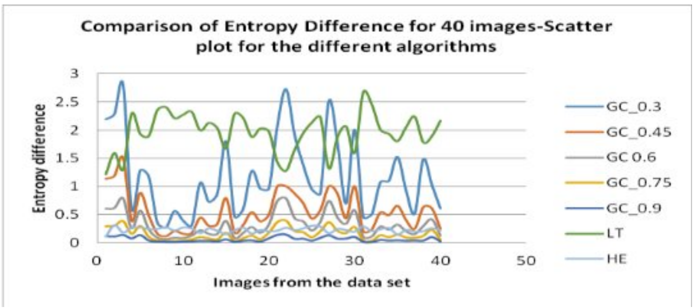

Figure.6. Scatter graph (for Table.4.) depicting the entropy difference of each algorithm for all 40 images.

Scatter graph shown in Figure.6 also shows that GC_0.9 has the minimum entropy difference for most of the input images from the data set. This shows that the Gamma Correction with gamma value 0.9 is the most suitable enhancement algorithm for this dataset. Table 5 gives details of the number of images in the data set for which a particular algorithm was ranked as 1^{st}, 2^{nd}, 3^{rd}, etc.

This analysis may vary, if a different data set is considered.

Table.5. shows the inference obtained from the survey from the survey of the dataset.

Algorithm	Rank1	Rank2	Rank3	Rank4	Rank5	Rank6	Rank7
GC_0.3	0	0	0	0	0	31	9
GC_0.45	0	0	0	7	30	3	0
GC_0.6	0	0	19	21	0	0	0
GC_0.75	0	32	8	0	0	0	0
GC_0.9	**39**	1	0	0	0	0	0
HE	1	7	13	12	7	0	0
LT	0	0	0	0	3	6	31

5. CONCLUSION

In this work a method for finding the best possible enhancement algorithm for a given image and dataset has been proposed. There are lot of image enhancement methods available but it has been observed that most of the techniques cannot be generalised for different types of images. The behaviour of each algorithm depends on the quality of the input image. The enhancement procedure selected must be based on the input image statistics. Here an automated system was developed that automates the process of image enhancement, in such a way that the decision of the enhancement parameters and the method is done, with the help of the image statistics (like mean, variance, entropy and standard deviation). The system also ranks the algorithms so that the end user can have a choice, as image quality has always been a subjective measure. This could be used as a pre-processing for any image processing application.

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