Image Enhancement Algorithm Implemented on Reconfigurable Hardware

Pratik G. Jane
M. Tech, VLSI Design,
Electronics Department,
Ramdeobaba College of Engineering and
Management, Nagpur

Nitin P. Narkhede
Electronics Department,
Ramdeobaba College of Engineering and
Management, Nagpur

ABSTRACT
Present day applications require various kinds of images and pictures as sources of information for interpretation and analysis. Whenever an image is converted from one form to another, such as digitizing, scanning, transmitting, storing, etc., some form of degradation occurs at the output. Hence, the output image has to undergo a process called image enhancement which consists of a collection of techniques that seek to improve the visual appearance of an image. This work addresses the implementation of image enhancement algorithms like global contrast adjustment, local contrast adjustment and global histogram equalization on FPGA (using soft core processor) that have become a competitive alternative for high-performance image processing applications.

Keywords
Contrast stretching, Local Contrast stretching, Global Histogram Equalization, soft core processer, micro-blaze.

1. INTRODUCTION
Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or machine. Meanwhile, the term image enhancement means the improvement of an image appearance by increasing dominance of some features or by decreasing ambiguity between different regions of the image.

Histogram can be defined as the graphical distribution of pixels over the range of the gray value, for any gray scale images pixel gray value ranges from 0 to 255. Histogram plot for gray scale image is shown in fig. 1(a) [2]. The ideal gray scale image histogram is perfectly flat and makes use of every available gray value in the image format shown in the fig. (1b).

Histogram expansion is a technique of histogram equalization [2]. This paper has described three different techniques of histogram expansion namely global contrast expansion, local contrast expansion and global histogram equalization. These are term as point processing operations on image. Contrast stretching is the method in which the histogram of the narrow region is stretch to the entire gray scale of histogram plot [1]. Generally, these methods are classified into two principle categories; global contrast stretching (GCS) and local contrast stretching (LCS) [10]. In the GCS the entire image pixels take into account for histogram expansion. But in the LCS used sliding window method in which, for each pixel local contrast value are computed from the windowed neighborhood to produce a local grey level remapping for each pixel. LCS is capable of great contrast enhancement.

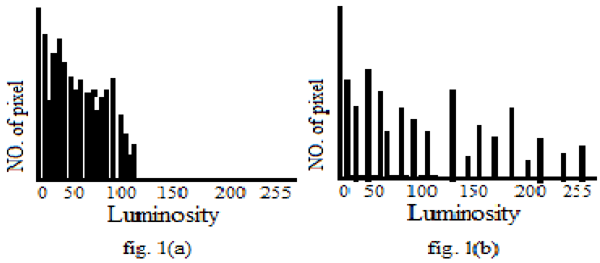


Fig 1: histogram plot; (a) histogram plot of the dark image in which gray value is from 0 to 125; (b) histogram plot of ideal gray scale image in which gray value is from 0 to 255.

Global Histogram equalization (GHE) is a very popular technique for enhancing the contrast of an image [1, 2]. Histogram operations are designed to enhance the visibility of objects of interest in an image. Which is simple and has good performance compared to nearly all types of images. GHE performs its operation by remapping the gray levels of the image based on the probability distribution of the input gray value [3, 7]. It flattens and stretches the dynamic range of the image's histogram, resulting in overall contrast improvement [4]. This transformation increases the user sensation to the field of view by making the transformed image is more suitable than the original image for the intended application. Global HE (GHE) uses the histogram information of the entire input image for its transformation function.

Field programmable gate array (FPGA) is a large-scale integrated circuit that can be re-programmed. FPGA has a large impact in image and video processing; this is due to the potential of the FPGA to have parallel and high computational density as compared to a general purpose microprocessor [5]. Recent advancements in FPGA technology have resulted in FPGA devices that support the implementation of a complete computer system on a single FPGA chip. A soft-core processor is a central component of such a system. A soft-core processor is a microprocessor defined in software usually in an HDL, which can be synthesized in programmable hardware, such as FPGAs.

2. IMAGE ENHANCEMENT ALGORITHM

2.1 Contrast stretching
Medical imaging uses contrast stretching for reducing noise and sharpening details to improve the visual representation of the image. If low contrast image is resulted due to low light conditions, lack of dynamic range of the camera sensor, contrast stretching operation results in the good quality image. During the contrast

stretching operation, we basically increase the dynamic range of the gray values in the image being processed.

2.1.1 Global Contrast Stretching

In the GCS the entire image pixels take into account for histogram expansion. Contrast stretching algorithm works as follows [1]:

$$IN(r,c) = (I(r,c) - Min)\frac{(newMax - newMin)}{(Max - Min)} + newMin$$

I(r, c) is the gray level for the input pixel(r, c) and ***IN(r, c)*** is the gray level for the output pixel (r, c) after the contrast stretching process. ***Max*** and ***Min*** are the maximum and minimum gray level in the input image. The ***newMax*** and ***newMin*** are the desired maximum and minimum gray levels that determines gray level range of the output image, respectively.

GCS having some limitation, it can't enhance those images that are having minimum gray level '0' and maximum gray level '255'. For that kind of images, a local contrast stretching is required that will be described in the next section.

2.1.2 Local Contrast Stretching

The LCS is done by breaking the input image into fixed size overlapping windows, and then local contrast value for all the pixels are computed from the windowed neighborhood to produce a local grey level remapping for each pixel [10].

Local contrast stretching is done by using following algorithm.

Let $x(i,j)$ be the gray value of a pixel in an image. The local area is define as a $(2n+1)$* $(2n+1)$ window centered at (i,j) where *n* is an integer number. Let $F(i,j)$ denote the enhanced value of $x(i,j)$.

$$F(i,j) = Mx(i,j) + D * (\frac{x(i,j) - Mx(i,j)}{6x(i,j)})$$

$Mx(i,j)$ Is the local mean, $6x(i,j)$ is the Local Standard deviation (LSD) and D is a constant. The mean of local area is calculated as,

$$Mx(i,j) = \frac{1}{(2n+1)^\wedge 2}\sum_{k=i-n}^{i+n}\sum_{l=j-n}^{j+n} x(k,l)$$

The local standard deviation of the local area is calculated as,

$$(6x(i,j))^\wedge 2 = \frac{1}{(2n+1)^\wedge 2}\sum_{k=i-n}^{i+n}\sum_{l=j-n}^{j+n}[x(k,l) - Mx(i,j)]^\wedge 2$$

2.2 Global Histogram Equalization

For a given image X, the probability density function $P(Xm)$ is defined as [6, 8]

$$P(Xm) = \frac{n_m}{n}$$

For *m = 0, 1… L–1*is the gray level, where n_m represents the number of times that the level Xm appears in the input image X and *n* is the total number of samples in the input image. Note that $P(Xm)$ is associated with the histogram of the input image which represents the number of pixels that have a specific intensityXm. In fact, a plot of n_m *vs.* Xm is known histogram of X. Based on the probability density function; the cumulative density function is defined as

$$c(x) = \sum_{j=0}^{m} P(X_j)$$

Where Xm= *x*, for *m = 0, 1… ,L–1*. Note that *c* (X_{L-1}) = 1 by definition. HE is a scheme that maps the input image into the entire dynamic range, (X_0,X_{L-1}), by using the cumulative density function as a transform function. Let's define a transform function $f(x)$ based on the cumulative density function as

$$f(x) = X_0 + (X_{L-1} - X_0)c(x)$$

Then the output image of the HE, *Y = {Y (i, j)}*, can be expressed as

$$Y = f(X) = \{f(X(i,j)/\forall\, X(i,j) \in X\}$$

The high performance of the GHE in enhancing the contrast of an image as a consequence of the dynamic range expansion, besides, GHE also flattens a histogram. Based on information theory, entropy of message source will get the maximum value when the message has uniform distribution property.

3. SYSTEM DESIGN

For the hardware implementation of the image enhancement algorithm, first we need to convert the image into the text file format. HDL languages do not support image files. So we have converted images in to text files. In these text files gray level values of pixels are saved. Microblaze (MB) processor system is created using Xilinx EDK tool. The MB system is targeted for Digilent Spartan 3E Starter Board. Text file of image is stored in Microblaze RAM. C language program is written for global, local and algorithms. MB system gives the enhanced image on UART.

4. RESULT

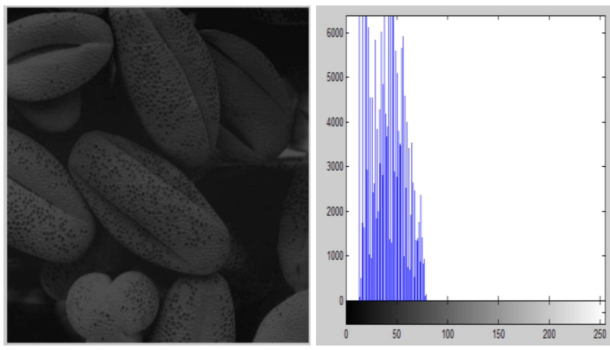
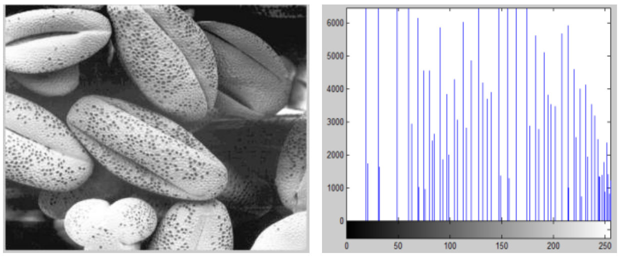
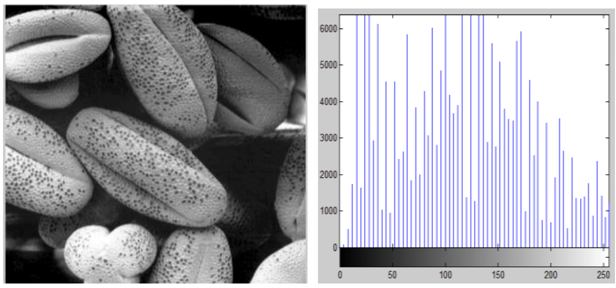


Fig 2(a): **(b)**



(c) **(d)**



(e) **(f)**

Fig 2: the image of bottom_left provided with matlab, 2(a) original image, 2(b) histogram plot (a), 2(c) result of GHE, 2(d) histogram plot (c), 2(e) result of GCS, 2(f) histogram plot (e).

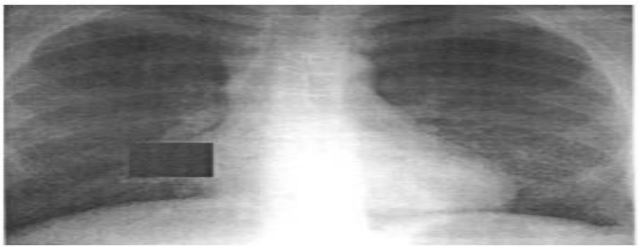


Fig 3 (a).

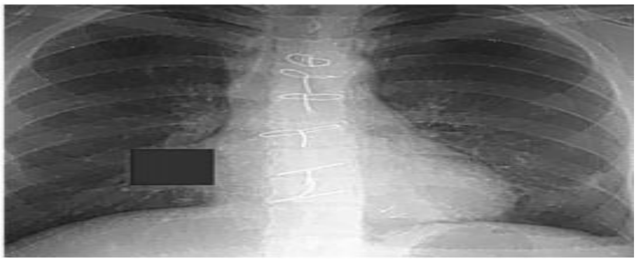


Fig 3 (b).

Fig 3: the image of x-ray provided with matlab, 3(a) original image, 3(b) result of LCS.

The figure 2(a) is the test image (bottom_left) taken from the matlab library. The histogram plot of the test image is situate in small low intensity region therefore it will hide the fine detail in the image and entire image will be covered by shadow. We apply GHE to test image it will enhance the image and make visible all the detail. The histogram plot of GHE apply image is stretch but it will not used all the gray value available. If we apply GCS to test image it will give enhance image and used all the gray level available.

The figure 3(a) is the test image (x-ray) taken from the matlab library. We apply GCS to that image it will suppress the noise in that image and enhance the fine detail.

5. DEVICE UTILIZATION SUMMARY

Table 1. Information about fpga utilization

Design	Flip-flops	LUT's	I/O Blocks	Block RAM's	GCLKs
All three	2,809	3,206	85	13	3.27

6. CONCLUSION

The paper describes a variation of Histogram expansion which uses both local and global information in order to achieve a more strict partial order on the image pixels.

This paper investigates the implementation of global contrast stretching, local contrast stretching and also global histogram equalization algorithm on FPGA. The algorithms were implemented on Digilent Spartan 3E Starter Board using microblaze (soft core processer) provided by Xilinx. The implementation result is given. Also, for all the algorithms, number of logic elements utilized is listed. The implementation of the all three algorithm on the FPGA using soft core processer is faster than the simple FPGA implementation.

7. REFERENCES

[1] S. Sowmya and Roy Paily, "Fpga Implementation of Image Enhancement Algorithm" ©2011 IEEE.

[2] Jasdeep Kaur, Nancy, Ramneet Kaur and Nishu "Histogram Expansion A Technique of Histogram Equalization" IJRET| MAY 2013.

[3] Hyunsup Yoon, Youngjoon Han and Hernsoo Hahn "Image Contrast Enhancement Based Sub-Histogram Equalization Technique without Over- Equalization Noise" IJEEE 2009.

[4] Mark ramian and David Mould "Histogram Equalization Using Neighborhood Metrics" ©2012 IEEE.

[5] Earnet Jamro, Maciej Wielgosz, Kazimierz Wiatr,"FPGA Implementation Of Strongly Parallel Histogram Equalization," IEEE Int. conf. on image processing. 2011, 1-4244-1161-0 ©2007 IEEE.

[6] Abdullah M. Alsuwailem, Saleh A. Alshebeili, "A New Approach For Real-Time Histogram Equalization Using Fpga" IEEE Int. proceeding of 2008 2010, 0-7803-9266-3/05.

[7] Rajesh Garg, Bhawna Mittal, Sheetal Garg, "Histogram Equalization Technique For Image Enhancement". IJECT Vol. 2, ISSUE 1, MARCH 2011.

[8] Stephanie Parker, J. Kemi Ladeji-Osias, "Implementing a Histogram Equalization Algorithm in Reconfigurable Hardware," IEEE Int. conf. on image processing. 2010.

[9] Mrs. Nitin Sachdeva, Tarun Sachdeva, "An FPGA Based Real-time Histogram Equalization Circuit for Image Enhancement," IJECT, ISSN: 2230-7109(Online), DECEMBER 2010.

[10] S. Somorjeet Singh, Th. Tangkeshwar Singh, H. Mamata Devi, Tejmani Sinam "Local Contrast Enhancement Using Local Standard Deviation", IJCA(0975-888) Vol. 47- No. 15, June 2012.