An Implementation of Image Enhancement on Real Time Configurable System using HDL: A Review

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Abstract— **whenever the one form of image is converted to another form, the degradation occurs in the quality of the original image. Therefore to improve the visuality of the image, the image enhancements techniques are used for the improvements. These Techniques are the contrast stretching, brightness control, invert operation, threshold operation etc. The image enhancement can be done with the help of the both software implementation and hardware implementation. But as the hardware implementation has better performance than the software implementation therefore we use the configurable system that is in real time to enhance the image quality. Image processing with the help of hardware description languages is the technique with new approach in the area of digital system design using VLSI.**

Index Terms— **FPGA, Digital Image Processing, VLSI, Verilog, HDL, Image Enhancement**

I. INTRODUCTION

Image processing is the technique that is used to convert the image in to the digital form and then perform some operation on it, to enhance the image quality. Mainly there are three major problems due to which image processing is developed, these are image digitization, image enhancement and restoration and image segmentation. A digital image is an image that has been represents using a discrete quantity both in the spatial coordinates and in the brightness. A digital image is formed of the pixels. This pixel is illuminated by the light. Grey level is the digitized brightness value and it is represented by 2b. The number of bits B, require to store the image with size a × a is given by

$$B = a \times a \times b \text{ bits}$$

Digital image processing (DIP) is the process to manipulate and analyze image with computer. Image enhancement can be done in the two domains. One is the Spatial domain techniques and other one is the frequency domain techniques.
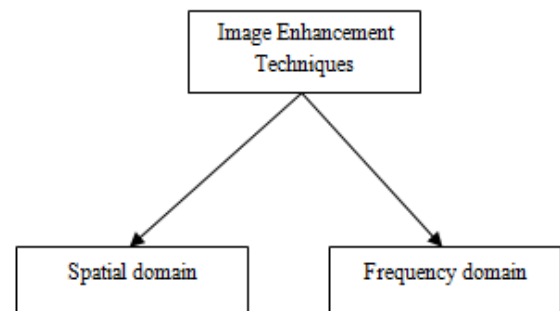

Fig.1 Domains for the implementation of the image enhancement

The spatial domain is mainly based on the direct implementation on pixels of the image where the frequency domain modifies the Fourier transform of an image for the improvement in the quality. The image enhancement in spatial domain the following processing methods are used like inverting image, contrast manipulation, threshold operation, brightness manipulation. Implementation of complex computational functions on the hardware with the help of parallelism and pipelining, it reduces the execution time. The features make FPGAs superior in speed as compared to other hardware. Therefore, for implementation of image processing, It is assumed that mainly impulse noise or Gaussian noise is present in the image. The impulse noise only affects the some pixels but the Gaussian noise affects the values of all pixels. The image is enhanced when we remove additive noise from image and increase its contrast and brightness.

II. REVIEW OF LITERATURE

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Luliana *et al*. [1]: have discussed the series of the filters to increase the quality of the image. In this paper HDL code is written in Verilog language for the filters of new series like edge detection and proper brightness.

Luliana *et al*. [3]: have discussed the image enhancement techniques with point operation by using the Verilog code that is a hardware description language. In this image is enhanced by using the point operation like brightness enhancement, contrast stretching, inverting and thresholding operations.

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Grigore T. Popa *et al*. [7]: have discussed the benefits of hardware implementation using Field Programmable Gate Array over software's for implementation of DIP applications. This described the implementation of configurable system in real time such as thresholding, inverting operation etc.

N Sachdeva *et al*. [16]: have discussed the implementation of mean formula using FPGA in hardware device..

Kalyani A. Dakre *et al*. [11]: have discussed the algorithm for the improvement of image quality. In this the algorithms like brightness control, thresholding, contrast stretching etc. is used.

Yahia said *et al*. [12]: have discussed to improve the time of implementation with the help of hardware description language (HDL) from a MATLAB description using Xilinx AccelDSP. block have proposed for 65nm CMOS technology. And also gain in forward loop to make the system stable.
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III METHODS OF IMAGE ENHANCEMENT

The methods given below are used to increase the visual quality of the images using point operations. The results of images processed are more suitable for the specific application than the original image.
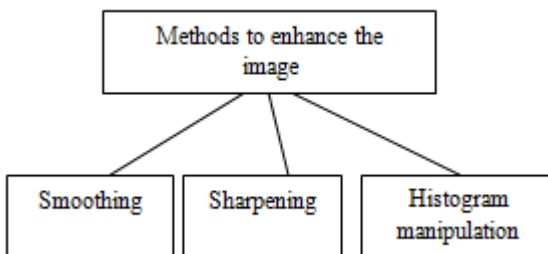

Fig. 2 Methods to enhance the image

Noise removal and contrast stretching are the operations that are usually used to increase the image quality. In this section discusses the generally used techniques, these are:

1) Brightness adjustment

2) Histogram Equalization

3) Contrast adjustment

A. Brightness Adjustment

With the help of energies recorded by sensors, the brightness for different pixels is created. Controlling brightness is the technique to increase the grey levels of each pixel such that it enhances the image quality with lower brightness. If the images are captured in poor light then the visuality of the image will not be clear. To resolve this problem, brightness adjustment is the good option and this shows the image clearer. But here we should the constant value wisely so that the grey value ranges within 0-255. If the grey level value increased above the 255, then it loses the information that the image carry. Brightness control algorithm is given by:

$$J_k(p, c) = \begin{cases} I_k(p, c) + h, & if\ I_k(p, c) + h <= 255 \\ 255, & if\ I_k(p, c) + h > 255 \end{cases}$$

H should be greater than or equal to Zero and k variable belongs to 1, 2 and 3 that is the band index. $I_k(p, c)$ is the color level of pixels of input and J k (p, c) is of output pixels (p, c). Therefore to modify the brightness, the grey level of image must be lies from 0 to 255.

B. Histogram equalization

The histogram of an image is that diagram which shows frequency of every intensity value from pixel element of image. The high value of the histogram shows that with this intensity the numbers of pixels is high. If the histogram value is low, then the total number of pixels exists in the image at that intensity is low. Brightness and contrast of the image can be shown by the histogram.

Consider an image with p × q pixels. The calculation for histogram can be given as

$$G(i) = \sum_{p=0}^{p} \sum_{q=0}^{q} k$$

Where k is equal to 1when f(p, q) is equal to i and k is equal to 0 when f(p, q) is not equal to i and f(p, q) shows the value of intensity at the co-ordinate (p, q) in image.

It allows lower contrast to acquire a higher contrast. This type of method is used for when both the foregrounds and backgrounds are bright and dark.

The formula for histogram equalization is given by:

$$G(v) = round\ \left(\frac{(cdf(v) - cdf_{min})}{(P \times Q) - cdf_{min}}(N-1)\right)$$

Cdf_{min} is the cumulative distribution function, P×Q provides the number of pixels where N shows quantity of grey levels in image.

C. Contrast Adjustment

Contrast adjustment technique is used to improve the image quality with the increment in intensity values. Contrast method is mostly used in the field of medical to

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enhance the image visibility. The image with low contrast may be obtained when the image is either captured in the low light or sensor of camera is not well.

IV.   PROPOSED ARCHITECTURE

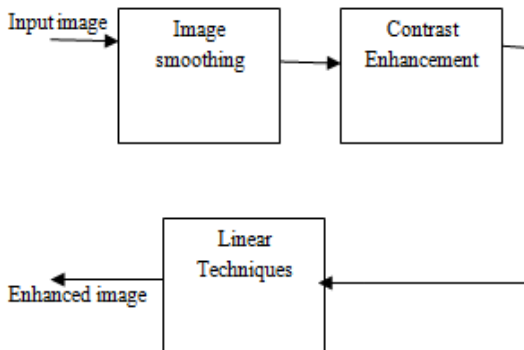In Figure 3, the proposed architecture is as shown.

Fig. 3   Architecture to be proposed

This architecture consists of three steps, these are the image smoothing, second one is the contrast enhancement and last one is the linear techniques .

A.   Image Smoothing

Smoothing techniques are used to reduce the noise present in the image. It also identified as a filter because it remove the high frequency from the image and increase the signal that have low frequency. The main aim of this technique is to decrease false pixel values effect in the image. Smoothing filter is also called low pass filter. It also reduces the irrelevant details. It blurs the edges of the image; it is one of the side effect.

In this process two operations takes place.

Moving window architecture: In this architecture take an image of 256×256 size and gives as the input. This masks the input and start to perform computation for each and every 3 by 3 matrices and this operation repeats itself till it performed the 65536 values. In this type of architecture D flip flops are used. D flip flops are shown in Fig 4.
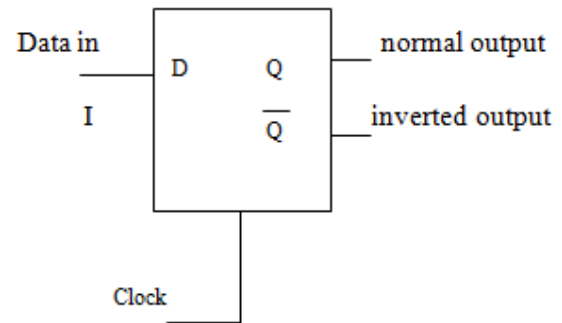
Fig. 4 D flip flop

Arithmetic mean filter: An arithmetic mean filter is used to remove the Gaussian noise that is present in the image. The arithmetic mean is the average of the pixels that are located in local area of the image.

Mean = (sum of brightness value observation) / (number of observations)

B.   Contrast Enhancement

Contrast enhancement is the simple technique to enhance the image by improving the contrast of the image. Wrong setting of lens aperture and poor illumination is the reasons for low contrast images.
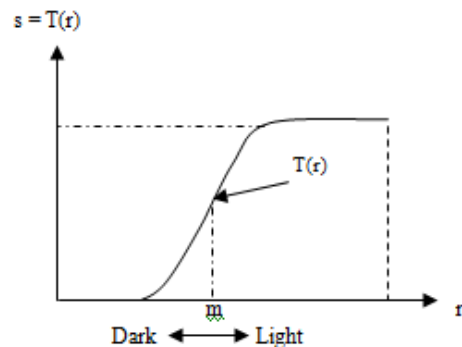
Fig.6 Representation of thresholding values

C.   Linear Technique

With the help of linear techniques, implementation of VLSI can be done easily for image enhancement. It plays the significant role w.r.t. hardware utilization. The hardware consists of an adder, two subtractors and a sifter for linear technique enhancement. Here shifter behaves like divider and the final result is received from the adder.

V. ARCHITECTURE OF IMPLEMENTED ALGORITHMS

In Figure 7, figure 8 and figure 9, the RTL schematic of the algorithms used for contrast stretching, brightness adjustment and histogram equalization respectively.
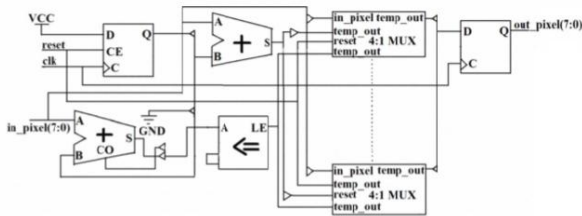

Fig. 7 Brightness adjustment (RTL schematic) [2]

The RTL schematic (brightness adjustment technique) consists the following circuits that are comparator, adder, D-flip flops, and 4 is to 1 multiplexer. Here the adder bit is of 8 bit used to add the brightness value to input pixels when the result of comparator is 1. And the output of comparator is true when the sum of brightness factor and input pixel is less than 255 otherwise it is a false value. And the multiplexer gives the output either the original pixel or modified pixel of the image. Output pixel is of 8 bit but the output of multiplexer is of 1 bit. Therefore in this architecture eight 4is to 1 mux are used.
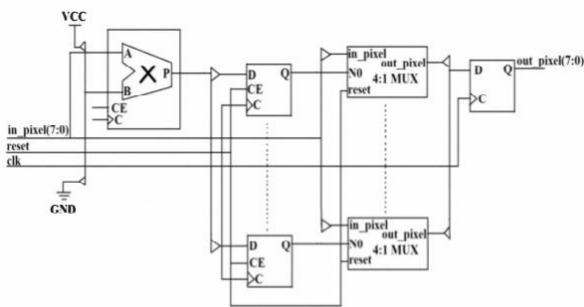

Fig. 8 RTL schematic of contrast adjustment technique [2]

This RTL schematic (contrast adjustment technique) consist D -flip flops, multiplier and 4 is to 1 mux. Multipliers are used to multiply the input pixel of 8 bit with a value of k. After multiplier eight D flip flops are used. Output pixel is of eight bit but the output multiplexer is of 1 bit therefore eight multiplexers are used in this.
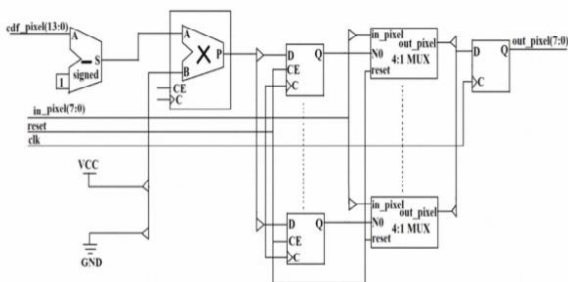

Fig. 9 RTL schematic of histogram equalization technique [2]

This RTL schematic (histogram equalization technique) consists of multipliers, D -flip flops, subtractor and 4 is to 1 multiplexer. Subtractor is used for the difference between cdf pixel of input and minimum cdf value. Multiplier multiplies the output of the subtractor with a constant factor. And then finally multiplier gives the modified values of pixel. Output pixel is of eight bit but the mux output is of one bit. Therefore eight 4×1 multiplexers are used to get the pixel output of eight bits.

VI. IMPLEMENTATION OF IMAGE PROCESSING ALGORITHM USING VERILOG CODE

In this section describe the implementation of point operation using Verilog HDL most commonly used for image improvement that are:
a) Brightness manipulation
b) Contrast operation
c) Inverting image
d) Thresholding

A. Brightness manipulation

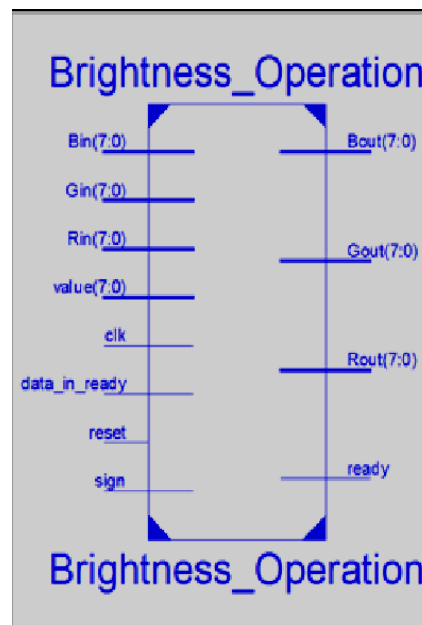Fig. 10 shows the Verilog block of point operation for brightness control.

Fig. 10 Verilog blocks for brightness operation [3]

The main aim of written Verilog code for brightness operation is to add or subtract the constant factor in pixel value of image.

Table 1 and Table 2 show the Verilog code to add up and subtract the constant factor from the pixel value. The addition operation increases the brightness or visibility of the image but the subtract operation reduce the image brightness.

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Table 1 Verilog code used for brightness manipulation (addition) [3]

```
if(sign1 == 1)
 begin
 tempR1 = Rin1 + value1;
if (tempR1 > 256)
Rout1 = 255;
 else
Rout 1= Rin1 + value1;
 tempG1 = Gin + value1;
 if (tempG1> 256)
Gout1 = 255;
 Else
 Gout1 = Gin + value1;
 tempB1 = Bin + value1;
 if (tempB1 > 256)
 Bout1 = 255;
 else
Bout1= Bin + value1;
 end
```
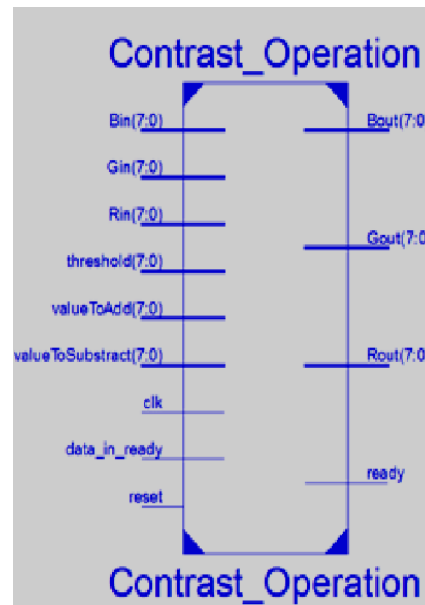

Fig. 11 Verilog blocks for contrast operation [3]

Table 3 and Table 4 show the Verilog code for contrast operation with addition and subtraction.

Table 2 Verilog code used for brightness manipulation (subtraction) [3]

```
if(sign == 0)
begin
tempR1 = Rin1 – value1;
 if (tempR1[8] == 1)
Rout = 0;
 else
Rout = Rin1 – value1;
 tempG1 = Gin – value1;
 if (tempG1[8] == 1)
Gout = 0;
 else Gout = Gin – value1;
tempB1 = Bin1 – value1;
 if (tempB1_b[8] == 1)
Bout 1= 0;
 else Bout1 = Bin1- value1;
 end
```

Table 3 Verilog code for contrast (addition) operation [3]

```
if (value > threshold1)
 begin
 tempR1 = Rin1 + valueToAdd1;
 if (tempR1 > 256)
 Rout = 255;
 else
 Rout = Rin1 + valueToAdd1;
 tempG1 = Gin + valueToAdd1;
 if (tempG1 > 256) Gout = 255;
else Gout = Gin + valueToAdd1;
tempB1 = Bin1 + valueToAdd1;
 if (tempB1 > 256) Bout 1= 255;
else
 Bout1 = Bin1 + valueToAdd1;
End
```

B. Contrast operation

  Fig. 11 shows the Verilog block of point operation for contrast control.

Table 4 Verilog code for contrast (subtraction) operation [3]

```
if (value < threshold1)
begin
 tempR1 = Rin1 – valueToSubstract1;
 if(tempR1[8] == 1)
Rout1 = 0;
else
 Rout1 = Rin1 – valueToSubtract1;
tempG1 = Gin 1– valueToSubtract1;
 if(tempG1[8] == 1) Gout1 = 0;
else
 Gout1 = Gin1 – valueToSubtract1;
tempB1 = Bin1 – valueToSubtract1;
```

```
if(tempB1[8] == 1)
Bout1 = 0;
 else
Bout1 = Bin1– valueToSubtract1;
 End
```

C. Inverting Image

In this operation reverse the all contrast range that produces the photographic negative. As an example X ray images are detected using negatives. Figure 12 shows the Verilog block for invert image processing.
Table 5 shows the Verilog code for inverting image processing.
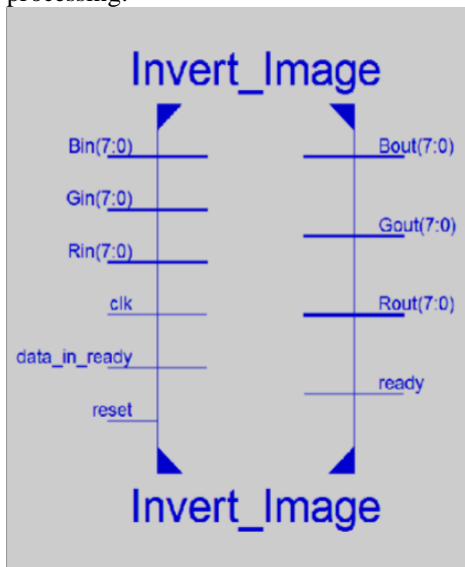

Fig.12 Verilog block for invert image operation [3]

Table 5 Verilog code used for inverting image operation [3]

```
value2 = (Rin1 + Gin 1+ Bin1)/2;
 value4 = (Rin1 + Gin 1+ Bin1)/4;
 value1  = (value2 + value4)/2;
 Rout 1= 255 – value1;
 Gout1 = 255 – value1;
 Bout1 = 255 – value1;
```

D) Thresholding

Thresholding method converts the all pixel values in two values. Figure 13 shows the Verilog block for thresholding operation.
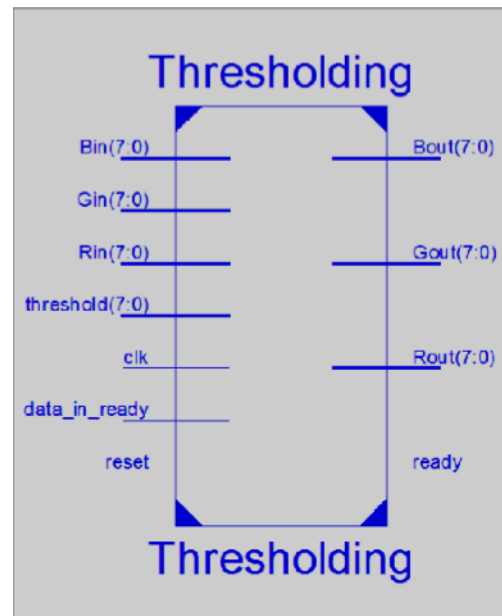

Fig. 13 Verilog code for thresholding operation [3]

Table 6 shows the Verilog code for the threshold operation. In this id the pixel value is greater than the threshold then red, green, and blue pixels contain the value 255 and if the pixel value is less then threshold then it take 0 values.

Table 6 Verilog code for thresholding operation [3]

```
if (value1> threshold1)
 begin
Rout 1= 255;
 Gout1 = 255;
Bout1 = 255;
end
 if (value1 < threshold1)
begin
 Rout1 = 0;
Gout1 = 0;
Bout 1= 0;
 End
```

VII. CONCLUSION

For signal processing use the hardware description languages is the quite new approach. It takes the input data in the HDL readable form and passed through the virtually circuit which described with Verilog HDL. And then again convert in to the signal. There are many important advantages when use this technique. One of the advantage is that hardware implementation is always better then the software implementation because of faster operation done by hardware.

Image enhancement methods provide a large variety of approaches to improve the visuality of the image. Input Image is enhanced either in spatial domain or in frequency domain. Here the operations for image enhancement are

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described by using the Verilog HDL. Verilog HDL cannot operate with the image format that's why first converting the image in to binary form. In this image enhancement methods are implemented by using the point operations like brightness operation, contrast stretching, inverting operation and thresholding operation.

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