A Novel Approach for FPGA Implementation of Pixel Level Image Fusion

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Abstract: **Image fusion is a technology which has great focus on research domain in recent years. As a result various methods of fusion techniques are proposed in fields of medical, remote – sensing, military and compute domains. Hardware implementations are adopted to tackle real time processing in different application domains. The images of various samples from same or different scenes are taken and they are fused and their coefficients are implemented on FPGA. Histogram Equalizer (HE) is adopted to detect the specified disease from scanned CT/MRI image, Adaptive Histogram Equalizer (AHE) and Principal Component Analysis (PCA) techniques are employed here for the fusion process, it results in clear and accurate diagnosis of particular MRI/CT image, the resulted fused image is implemented in FPGA for the purpose of diagnosis in medical domain, target detection in remote sensing and in military purpose.**

***Keywords*- Image fusion, histogram, PCA, FPGA**

I. INTRODUCTION

The term fusion means, a way to extract information acquired in several domains. Image Fusion is a method of integrating the relevant information from a set of images, into a single image, where the resultant fused image will be more informative and suitable for visual perception or processing than any of the input images considered separately.

Current technology in imaging sensors presents a wide variety of different information that can be extracted from an observed scene [11].

This technique is to combine the original input images to produce a different form of multiple images of pixel as an output. This content is organized and combined to provide an enhanced representation of the scene.

The image fusion methods involves the integration of various information sources thus the fused image more informative.

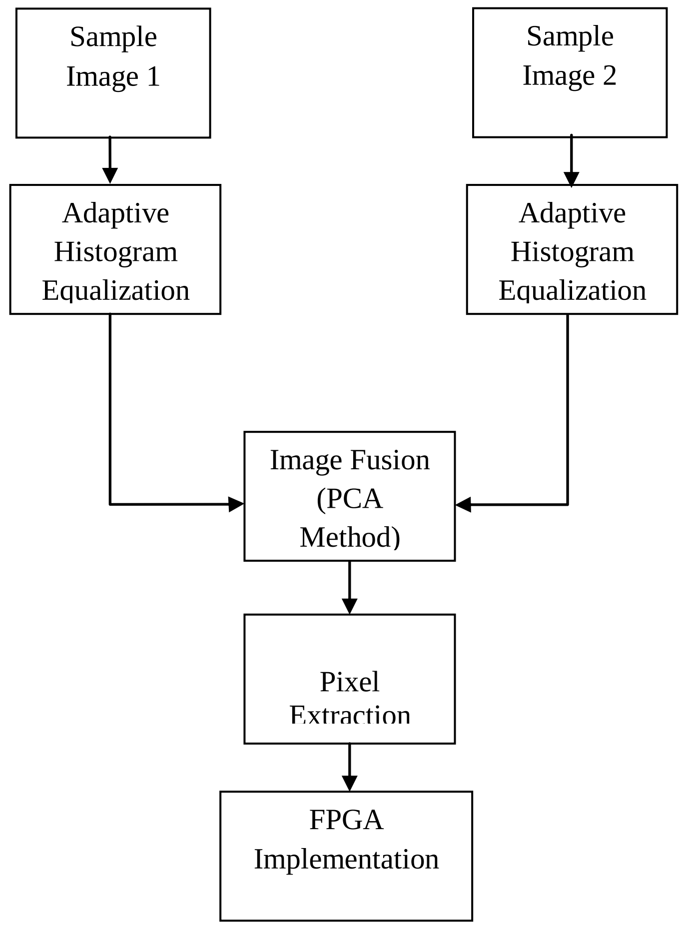


Fig 1.1 Block Diagram

Any fusion algorithm must satisfy two main requirements. Firstly, they must detect the most significant features in the input images and transfer them without loss of detail into the fused image.

Secondly, the fusion method should not bring in any inconsistencies or artifacts which would distract the human observer or following processing stages.

The samples of the images of various patients are taken from the libraries like bio science technology, radiology, brain map, neurosurgery, public medical image databases and cancer imaging archive, the CT and MRI images are taken and used as the sample of images for image fusion.

II. HISTOGRAM

An image histogram is a type of histogram which is a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value. On viewing histogram for a specific image a viewer will be able to judge the entire tonal distribution at a glance [9].

Image histograms are used in modern digital cameras. Photographers use this as a tool to show the distribution of tones captured, and whether image detail has been lost to blown-out highlights or blacked-out shadows.

The horizontal axis of the graph denotes the tonal variations, while the vertical axis denotes the number of pixels in that particular tone. The left side of the horizontal axis denotes the black and dark areas, the middle denotes medium grey and the right hand side denotes light and pure white areas.

The vertical axis denotes the size of the area that is captured in each one of these zones. Thus, the histogram for a very dark image will have the majority of its data points on the left side and centre of the graph. Histogram gives the global description for the appearance of the image [9].

The histogram of a digital image with gray values ro,r1,.....,rl-1 is given by the discrete function

$$p(r_k)=n_k/n \qquad (1)$$

n_k is number of pixels with gray value r_k.
n is total number of pixels in the image.

If we consider the gray values in the image as realizations of a random variable r, with some probability density, histogram provides an approximation to this probability density $p(r=r_k) = p(r_k)$

A. Histogram Equalization

The histogram gives the necessary information about intensity of the original input images. The intensity distribution of an image can be visualized clear and accurate. This technique improves the contrast in an image, in order to stretch out the intensity range.

A high-pass filter enhances the contrast of an image by re-evaluating the gray scale, or intensity, value of each pixel based on the values of nearby pixels in the same region. Images require a larger range of intensity values are displayed. Histogram equalization is a method to enhance the contrast of an area in an image by distributing an equal number of pixels across the range of intensities in the image[4].It processes each region by judging each pixel's location within this new histogram. Regardless of pixel value, the algorithm remaps the brightest pixel in each region to the brightest value in the histogram (i.e., 256) and remaps the darkest pixel to the lowest value in the histogram (i.e., 0) of the pixels in neighboring region, recording the new values as pixel intensity values.

Performing histogram equalization makes it possible to see minor variations within portions of the reference image that appeared nearly uniform in the source image. Arithmetically, the process in a region is rather simple

$$K = \sum_{i=0}^{j} \frac{N_i}{T} \qquad (2)$$

Where
N_i is the intensity of the ith pixel
T is the total number of pixels per region

The reference image using the new histogram is similar to the source image; however, in areas where the source image had similar values, the reference image is enhanced. The reference histogram now stretches over a greater proportion of the possible image intensities the histogram for the source image is very compact in structure; that is, it has a great number of darker pixels, but very few brighter pixels.

In fact, the bottom-most intensity values make up almost all of the pixels values in the image. Notice that different low areas of the reference image are more distinguishable depending on the number of rows and columns that divide the image. The contrast changes are due to which pixel is considered the brightest and which the darkest in a particular region. The brightest pixel in a 1 x 1 separated image is the brightest of the image.

However, when the image is divided into more regions, the brightest pixel in the region gets remapped as one of the brightest pixels in the image regardless of its absolute intensity in the image. The darkest pixel in the region is remapped as one of the darkest in the image regardless of its absolute intensity [4]. The histogram equalization process can enforce certain characteristics about the image called clipping. As the algorithm processes the image, it counts out the number of pixels of certain intensity.

III. PRINCIPAL COMPONENT ANALYSIS

Principal component analysis (PCA) is a method that transforms multivariate data with correlated variables into one with uncorrelated variables. They mainly used to reduce multidimensional data sets to lower dimensions for analysis.

It deals with the internal structure of data in an unbiased way since this fusion method may produce spectral degradation. The input images (images to be fused) I_1 (x, y) and I_2 (x, y) are arranged in two column vectors and their empirical means are subtracted.

The resulting vector has a dimension of n x 2, where n is length of the each image vector. The eigen vector and eigen values for this resulting vector are computed and the eigen vectors corresponding to the larger eigen value achieved [10]. The normalized components P_1 and P_2 (i.e., $P_1 + P_2 = 1$) are computed from the obtained an eigen vector.

The fused image is given by

$$I_f(x, y) = P_1 I_1(x, y) + P_2 I_2(x, y) \quad (3)$$

where $P_1$and P_2 are the normalized components

Basically it deals with two distinct applications of PCA in image processing. The first application consists in the image color reduction while the three color components are reduced into one containing a major part of information.

The second use of PCA takes advantage of eigen vectors properties for determination of selected object orientation [10]. This method provides a powerful tool for data analysis and pattern recognition which is often used in signal and image processing as a technique for data compression, data dimension reduction or their decorrelation as well. Covariance is such a measure.

Covariance is always measured between 2 dimensions. When we calculate the covariance between one dimension and itself, we get the variance. So, if you had a 3-dimensional data set (x,y,z) then you could measure the covariance between the x and y dimensions, the x and z dimensions, and the y and z dimensions. Measuring the covariance between x and x or y and y or z or z would give you the variance of the x, y and z and dimensions respectively. For two dimensional X and Y covariance is given by

$$COV(X,Y) = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{(n-1)} \quad (4)$$

PCA essentially calculates the set of points around their mean in order to align with the principal components. This moves as much of the variance as possible using a transformation into the first few dimensions. The values in the remaining dimensions, therefore, tend to be small and may be dropped with minimal loss of information. PCA is often used in this manner for dimensionality reduction. PCA has the distinction of being the optimal orthogonal transformation for keeping the subspace that has largest variance.

The PCA involves a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables. It computes a compact and optimal description of the data set. The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible.

First principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first. This component points the direction of maximum variance within this subspace. The third principal component is taken in the maximum variance direction in the subspace perpendicular to the first two and so on. The PCA is also called as Karhunen-Loève transform or the Hotelling transform. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. its basis vectors depend on the data set.

PCA is also a linear transformation that is easy to be implemented for applications in which huge amount of data is to be analyzed. It is a simple non-parametric method of extracting relevant information from confusing data sets. PCA is a useful statistical technique that has found application in fields such as face recognition and image compression, and is a common technique for finding patterns in data of high dimension.

PCA uses a vector space transform to reduce the dimensionality of large data sets. Using mathematical projection, the original data set, which may have involved many variables, can often be interpreted in just a few variables [10].PCA is widely used in data compression and pattern matching by expressing the data in a way to highlight the similarities and differences without much loss of information.

Fig 1.2 shows fusion of images of input images 1 and 2 and their coefficients V and D are calculated and fused image is given by I_f

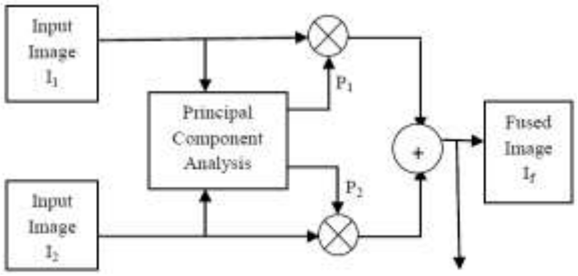


Fig 1.2 Block diagram of PCA [12]

A. *PCA Algorithm*

Let the source images (to be fused) of size *m* x *n* matrix, the steps for PCA are:

1. Arrange the data into column matrix. The resulting matrix *z* is of dimension 2 x *n*.
2. Calculate the empirical mean along each column. The empirical mean matrix *m* of 1 x 2.
3. Subtract the empirical mean vector *m* from each column of the data matrix *z*. The resulting matrix *x* is of dimension 2 x *n* i.e variance. Find the covariance matrix C of *x* and mean of expectation = cov(*x*) and $I_f = P_1 I_1 + P_2 I_2$
4. Determine the eigen vectors V and eigen value D of matrix C and sort them by decreasing eigen value. Both P_1 and P_2 are of dimension 2 x 2.
5. Consider the first column of V which corresponds to larger eigen value to compute coefficient P_1 and P_2.

IV. SIMULATION RESULTS

A. *Results For Image Fusion*

Samples of the images of various patients are taken from bio science technology, radiology, brain map, neurosurgery, public medical image databases and cancer imaging archive are taken and used as the sample of images for image fusion.

The computer tomography (CT) image and magnetic resonance imaging (MRI) image of brain of a different patient are taken for the reference and one of the samples of CT and MRI image is taken here for the fusion technique.

Fig 1.3 CT Image

The sample of CT image is referred and taken as the input image 1 and it is shown in fig 1.3

Fig 1.4 MRI Image

The sample of MRI image is referred and taken as the input image 2 and it is shown in fig 1.4

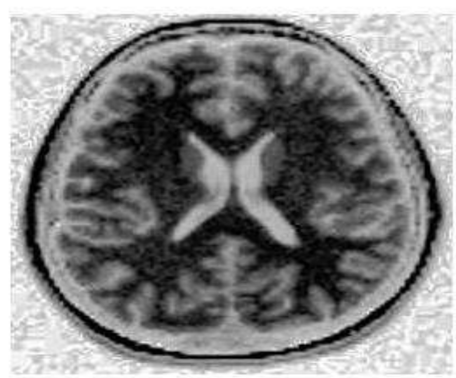


Fig 1.5 Histogram Equalization Of CT Image

The histogram equalization of CT image is shown in fig 1.5 it shows the sample of CT image after the histogram equalization done on the input sample image of CT, fig 1.5 provides the information of brain and the presence skeleton bones and ligaments are shown with better contrast

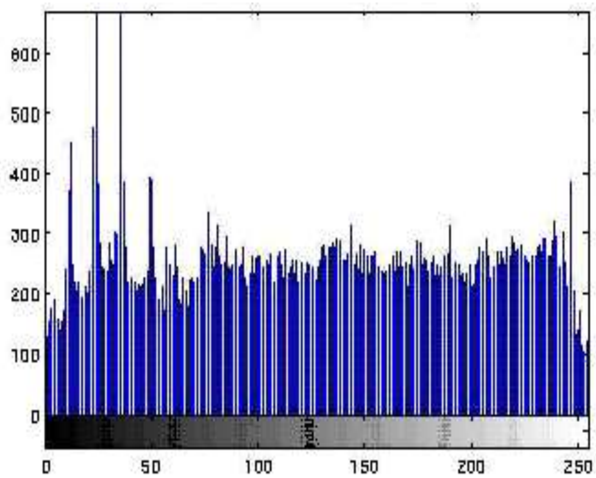


Fig 1.6 Histogram Equalization Graph of CT Image

The histogram equalization graph is plotted for the CT image is shown in fig 1.6 it shows the Variation of pixel in image is splitted in the range of 0 to 255 and the peak line provides the intensity of pixel.

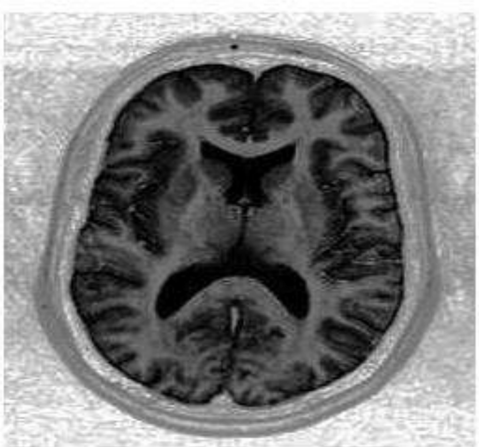


Fig 1.7 Histogram Equalization of MRI Image

The histogram equalization of MRI image is shown in fig 1.7 it shows the sample of MRI image after the histogram equalization done on the input sample image of MRI, fig 1.7 which provides the information of brain and the presence skeleton bones are shown with better contrast

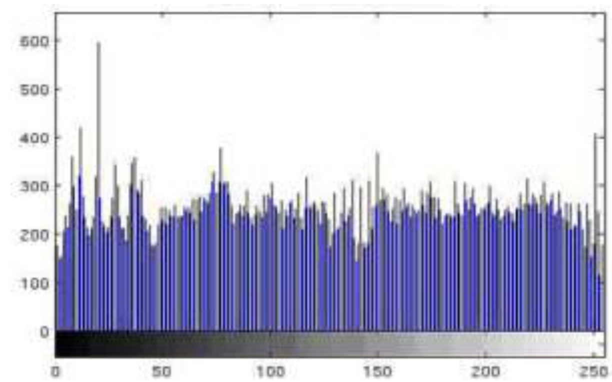


Fig 1.8 Histogram Equalization Graph of MRI Image

The histogram equalization graph is potted for the MRI image is shown fig 1.8 it shows the Variation of pixel in image is splitted in the range of 0 to 255 and the peak line provides the intensity of pixel

Fig 1.9 Fused Image

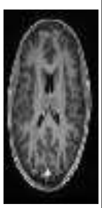
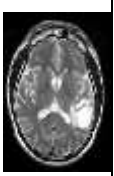
Fig 1.9 image shows the fusion of two images of CT and MRI and provide common ad mutual information than the individual images as given as the input samples.

The fused image provides for better visible and for improved contrast. It also provides the integrated information of individual image samples take here. The accurate diagnosis and treatment can be made for cancer, tumor and minor injuries with the help of the fused image with better contrast and resolution. The PCA algorithm is used as technique for the fusion of images and the coefficient and eigen values for the image is noted for the future work. The diagnosis and treatment of disease can be made better with the fused image.

B. Analysis Of Image Fusion

Several samples of the images of different patients are taken from the image database and they are used for the fusion and the coefficients and eigen Values are calculated and they are shown in table 1.1.

The fusion method adopted is PCA and their coefficients are noted and listed in table as well as eigen Values are listed in table 1.1 shown below

Sl no	Sample image 1	Sample image 2	Fused image	Coefficient V	Eigen value D
1				0.5672 -0.8236 -0.8236 -0.5672	0.3308 8.0168
2				-0.9675 0.2530 0.2530 0.9675	0.6444 5.8553
3				-0.7101 0.7041 0.7041 0.7101	1.3561 5.1359
4				-0.8476 0.5307 0.5307 0.8476	0.7927 5.8544

V. CONCLUSION

Image fusion has attracted a lot of interest, mainly in the fields of remote sensing and computer vision, while hardware implementations have been also presented to tackle real-time processing in different application domains**.** The histogram equalization technique is applied here for the good contrast and resolution of the fused image as well as Canny Edge Detection is also used to detect the corners of image. Image fusion technique is adopted in Medical domain.

Sample of Images are taken and adaptive histogram equalization technique is applied to enhance the image for good contrast. The Image Fusion is employed to get the common and mutual information utilized for the better information of individual images, also result in good contrast. The relevant information of image such as coefficient and Eigen Value are taken from a single image from sets of image of the image using MATLAB tool.

In future the coefficients and the pixel extracted from fused image and implemented on the Field Programmable Gate Array and the reduction area and power is analyzed. FPGA technology provides a fast, compact, and low-power solution for image fusion. The Field Programmable Gate Array implementation of the image can be used for the application of Medical Domain**.**

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