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Visual and Quantitative Analysis of Spatial Domain Techniques

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ABSTRACT: In radiology and radiation oncology PET AND MRI images serve different purposes. For example, PET images are used more often to ascertain differences in tissue density while MRI images are typically used to diagnose brain tumors. For accurate diagnoses, radiologists must integrate information from multiple image formats. Fused, anatomically consistent images are especially beneficial in diagnosing and treating cancer. With the advent of these new technologies, radiation oncologists can take full advantage of fusion of two images. Being able to overlay diagnostic images onto radiation planning images results in more accurate IMRT target tumor volumes. Numerical statistical methods such as RMSE, PSNR, Entropy are used to quantitatively assess fused images produces using above algorithm. The analysis indicates averaging and square root are the best spatial domain techniques as far as the medical images are considered.

KEYWORDS*:* MRI,PET,RMSE,PSNR

I. INTRODUCTION

Any piece of information makes sense only when it is able to convey the content across. The clarity of information is important. Image Fusion is a mechanism to improve the quality of information from a set of images. By the process of image fusion the good information from each of the given images is fused together to form a resultant image whose quality is superior to any of the input images. This is achieved by applying a sequence of operators on the images that would make the good information in each of the image prominent. The resultant image is formed by combining such magnified information from the input images into a single image. [1] Image Fusion is a framework where a composite image can be produced, that contains enhanced or simply better information about the target or scene compared to individual source images. Image Fusion had its beginning with the concept of simply averaging the intensities of the corresponding pixels of the set of input images, thus producing a fused image. A lot of advancements have happened in the field of image fusion since then employing advanced methods like Discrete Wavelet Transforms and Pyramidal Methods to fuse images.

Image fusion methods can be broadly classified into two - *spatial domain fusion* and *transform domain fusion*. The fusion methods such as averaging method, Brovey method, principal component analysis (PCA) and high pass filtering based technique are examples of spatial domain fusion methods. Here the high frequency details are injected into upsampled version of MS images. [2][5]The disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image. Spectral distortion becomes a negative factor while we go for further processing, such as classification problem, of the fused image. The spatial distortion can be very well handled by transform domain approaches on image fusion.[5][6]

II. IMAGE FUSION TECHNIQUES

Image Fusion techniques, though initially developed as an image quality enhancement technique, finds practical application in medical field and satellite imaging. The concept of multivariate image fusion now promotes research into fusing simple optical images, medical images and satellite images ranging through the multi spectra. For example, in

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medical imaging, two types of images are available. Image fusion has become a common term used within medical diagnostics and treatment. The term is used when multiple images of a patient are registered and overlaid or merged to provide additional information. Fused images may be created from multiple images from the same imaging modality or by combining information from multiple modalities such as magnetic resonance image (MRI), computed tomography (CT), positron emission tomography (PET). Many methods exist to perform image fusion. The very basic one is the high pass filtering technique. Later techniques are based on DWT, uniform rational filter bank, and pyramidal methods. There are numerous methods that have been developed to perform image fusion. Some well-known image fusion methods are listed below [1]:-

- Intensity-hue-saturation (IHS) transform based fusion
- Principal component analysis (PCA) based fusion
- Multi scale transform based fusion
- High-pass filtering method
- Pyramid method
- Wavelet transforms

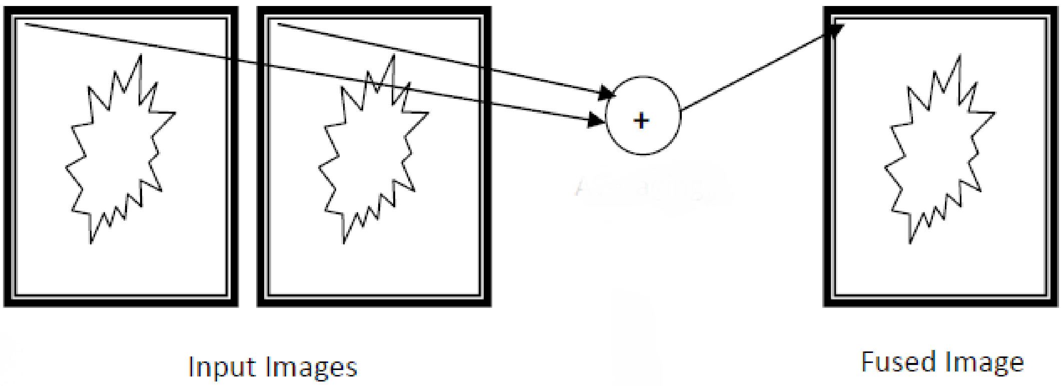
A. Spatial Domain Methods

The trivial image fusion techniques mainly perform a very basic operation like pixel selection, addition, subtraction or averaging. These methods are not always effective but are at times critical based on the kind of image under consideration. Following are some of the trivial image fusion techniques studied and developed as part of the project:

B. Additive Method

Image Fusion saw a similar background, wherein the most simplistic was to fuse a set of input image was to add the pixel intensities of the corresponding pixels. The fused image produced by this method projects both the good and the bad information from the input images. Due to the adding operation, we get a low contrast and high brightness fused image. Thus the algorithm does not actually fuse the images perfectly. The algorithm, being the simplest one, can be put in one step as the following:

- Calculate the addition of each corresponding pixel of the pair of input images.



Block Diagram of Additive Method

The above block diagram depicts the visual implementation of additive method.

C. Average Method

As mentioned previously in this paper, the very concept of information fusion arose from the idea of averaging the available information. Image Fusion also saw a similar background, wherein the most simplistic was to fuse a set of input image was to average the pixel intensities of the corresponding pixels. The fused image produced by this method projects both the good and the bad information from the input images. Due to the averaging operation, both the good

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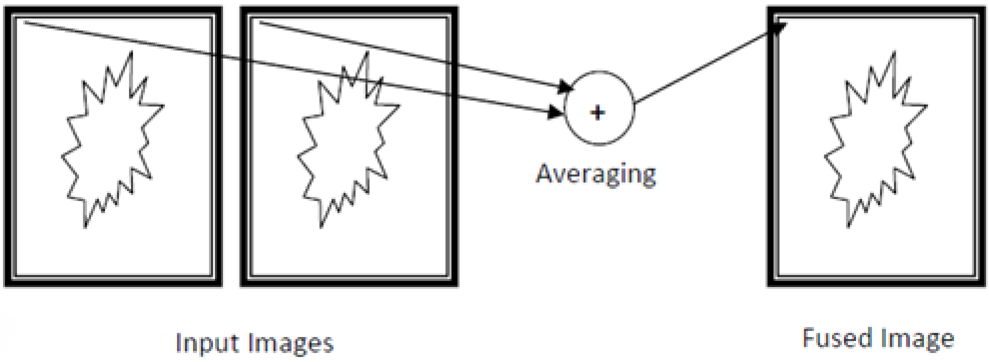
and the bad information are minimized arriving at an averaged image. Thus the algorithm does not actually fuse the images perfectly. The algorithm, being the simplest one, can be put in one step as the following:

- Calculate the average intensity value of each corresponding pixel of the pair of input images as shown below:



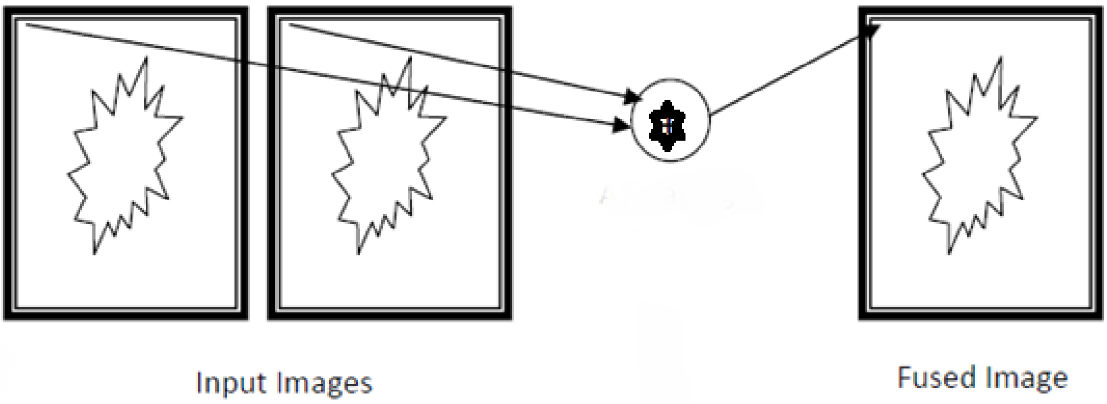
Block Diagram of Average Method

The above block diagram depicts the visual implementation of average method.

D. Multiplicative Method

The most simplistic was to fuse a set of input image was to add the pixel intensities of the corresponding pixels and then came into picture multiplicative method. However in this method two pixels are multiplied which reduced the intensity of image hence resulting in a dark image. The fused image produced by this method projects both the good and the bad information from the input images. The algorithm, being the simplest one, can be put in one step as the following:

- Calculate the multiplication of each corresponding pixel of the pair of input image



Block Diagram of Multiplicative Method

The above block diagram depicts the visual implementation of multiplicative method.

E. Square root Method

The most simplistic was to fuse a set of input image was to add the pixel intensities of the corresponding pixels and then came into picture multiplicative method. However to improve further after multiplying two pixels square root was take which brought a drastical improvement. The fused image produced by this method projects both the good and the bad information from the input images. The algorithm, being the simplest one, can be put in two step as the following:

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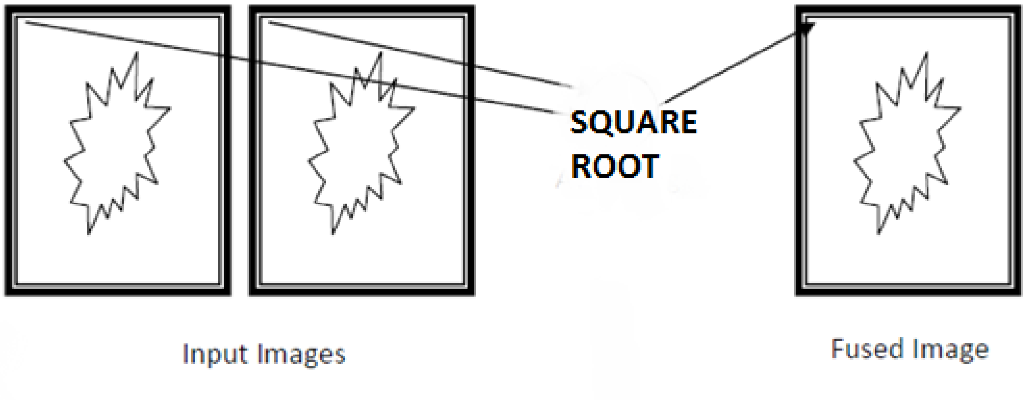
- Calculate the multiplication of each corresponding pixel of the pair of input images.
- Then take the square root of the obtained result.



Block Diagram of Square Root Method

The above block diagram depicts the visual implementation of multiplicative method.

III. ASSESSMENT PARAMETERS

We need specific analysis criteria in order to measure and evaluate the performance of the experimental results. Qualitative and quantitative inspections are two major means to evaluate the performance of distinct fusion schemes. However, qualitative approaches may contain subjective factors and can be influenced by personal preferences or eyesight. Due to these problems, quantitative approaches are often required and more desired to evaluate the experimental results.

i.Entropy

Entropy is defined as amount of information contained in a signal. Shannon was the first person to introduce entropy to quantify the information.The entropy of the image can be evaluated as

$$E = -\sum_{i=0}^{L-1} p_i \, log_2 \, p_i$$

Where L is the total of grey levels, $p = \{p0, p1, \ldots . . -1\ \}$ is the probability distribution of each level.
When fused image has relatively uniform frequency content then it contains maximum entropy. Greater entropy for fused image indicates more information contents than original images.[4] Entropy can directly reflect the average information content of an image. The maximum value of entropy can be produced when each gray level of the whole range has the same frequency. If entropy of fused image is higher than parent image then it indicates that the fused image contains more information.

ii.Root Mean Square Error (RMSE)

A commonly used reference-based assessment metric is the root mean square error (RMSE). This ratio is used as a quality measurement between the original and a reconstructed image. The higher the value of RMSE, the better is the quality of reconstructed image. It is defined as follows:

$$RMSE = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}(R(m,n) - F(m,n))^2}$$

where R(m,n) and F(m,n) are reference and fused images, respectively, and M and N are image dimensions.[10]

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iii.Peak Signal to Noise Ratio (PSNR)

PSNR computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is used as a quality measurement between the original and a reconstructed image. The higher the PSNR, the better is the quality of the reconstructed image. To compute the PSNR, first we have to compute the mean squared error (MSE) using the following equation:

$$PSNR(R,F) = 10\, log_{10} \frac{N^2}{MSE(R,F)}$$

Peak depends on the input image maximum fluctuation.

IV. Input Data

Overhere the two biomedical images have been shown. As we can see in the image 1 is MRI scan of brain and image 2 is PET scan of brain.

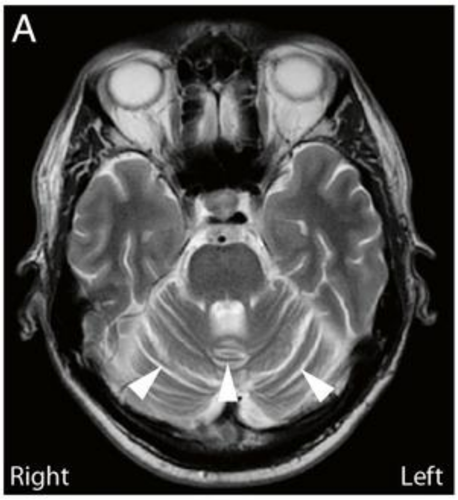

Fig. 1 MRI SCAN

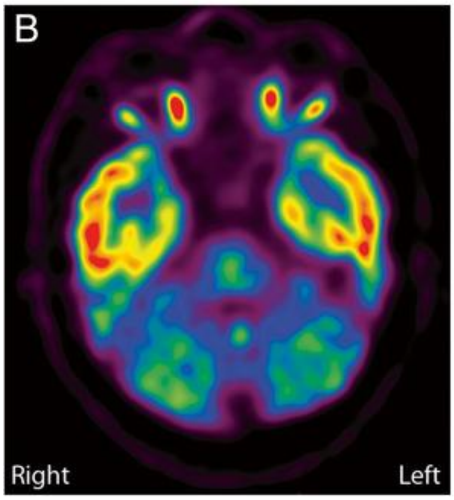

Fig.2 PET SCAN

Fig.1 & Fig. 2 are the MRI and PET scan of human brain respectively which are used for analysis in this paper

V. Results

In order to fully utilize spectral information of former and geometric information of latter, image fusion algorithm is applied to the set of input images. All the methods explained above were implemented using Matlab software.

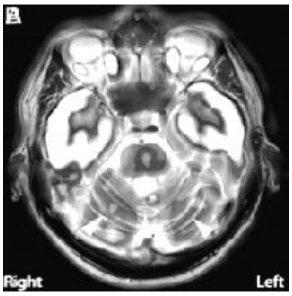

Fig 3 fused image by Additive method

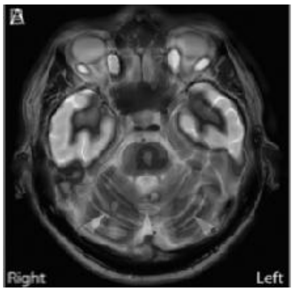

Fig 4 fused image by Average method

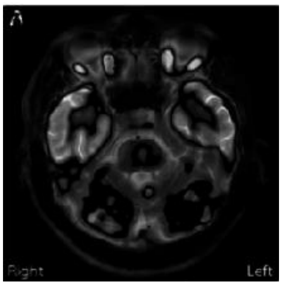

Fig 5 fused image by Multiplicative method

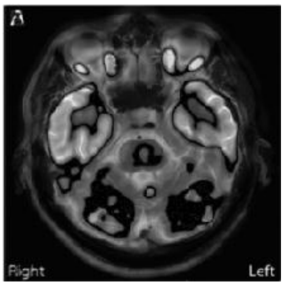

Fig 6 fused image by Square Root method

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Description & Visual analysis: The above shown images are the resultant fused images by applying the described algorithms.If we observe the above images, we can say that Average method gives better results among all the four methods although square root method concentrates on important parts of image .

VI.COMPARATIVE ANALYSIS

Here we have shown the table consisting of different parameters of image which will help us in understanding of different techniques and prove us which provides the best outcome.

METHOD	ENTROPY	RMSE 1 Fused + Image 1	RMSE 2 Fused + Image 2	PSNR 1 Fused +Image 1	PSNR 2 Fused +Image 2	CORR 1 Fused+ Image 1	CORR 2 Fused+Image2
ADDITIVE	6.76	0.3161	0.4154	53.13	51.94	0.8595	0.8033
AVERAGE	6.67	0.1502	0.1519	56.36	56.31	0.8595	0.8033
MULTIPLY	4.90	0.298	0.185	53.38	55.44	0.6264	0.75
SQUARE ROOT	6.54	0.2144	0.1565	54.818	56.18	0.7172	0.757

VII.CONCLUSION

This paper analyze and compare four different methods of medical image fusion with the help of visual and quantitative methods. Considering all the assessment parameters for spatial domain techniques and after performing the quantitative analysis we can conclude that for the set of biomedical images average method provide best resultsalthough the square root method concentrates on highly important parts of image.

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