RESEARCH ARTICLE OPEN ACCESS

Development and Comparison of Image Fusion Techniques for CT&MRI Images

Fatima*, Anitha Kulkarni**
**(Department of Electronics and Instrumentation, VNR VJIET, Hyderabad*
*** (Associate Professor, Department of Electronics and Instrumentation, VNR VJIET, Hyderabad*

ABSTRACT
Image processing techniques primarily focus upon enhancing the quality of an image or a set ofimages to derive the maximum information from them. Image Fusion is a technique of producing a superior quality image from a set of available images. It is the process of combining relevant information from two or more images into a single image wherein the resulting image will be more informative and complete than any of the input images. A lot of research is being done in this field encompassing areas of Computer Vision, Automatic object detection, Image processing, parallel and distributed processing, Robotics and remote sensing. This project paves way to explain the theoretical and implementation issues of seven image fusion algorithms and the experimental results of the same. The fusion algorithms would be assessed based on the study and development of some image quality metrics.

Keywords: Average Difference (AD), Laplacian Mean Square Error (LMSE), Maximum Difference (MD), Mean Square Error (MSE), Normalized Absolute Error (NAE), Normalized Cross Correlation (NCC), Peak Signal to Noise Ratio (PSNR), Principal Component Analysis Method (PCA), Structural Content (SC), Structural Similarity Index Metric (SSIM).

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 asequence 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. Image Fusion finds it application in vast range of areas. It is used for medical diagnostics and treatment [1]. A patient's images in different data formats can be fused. These forms can include magnetic resonance image (MRI), computed tomography (CT), and positron emission tomography (PET). In radiologyand radiation oncology, these images serve different purposes. For example, CT images are used more

Often to ascertain differences in tissue density while MRI images aretypically used to diagnose brain tumors[5]. Image fusion is also used in the field of remote sensing wherein multivariate images like thermal images, IR Images, UV Images, ordinary optical image etc. can be fused together to get a better image taken from a satellite [8]. The project mainly required the study and implementation of the following 4 algorithms of Image Fusion [1] [2] [3].

- Averaging method
- Select Maximum method
- Select Minimum method
- Principal Component Analysis Method

The project also required the development of the following 9 Image Quality Metrics to assess the quality of the fused images with respect to a sample perfect image for a given pair of input images [10].

- Mean Square Error (MSE)
- Peak Signal to Noise Ratio (PSNR)
- Average Difference (AD)
- Normalized Cross Correlation (NCC)
- Maximum Difference (MD)
- Normalized Absolute Error (NAE)
- Laplacian Mean Square Error (LMSE)
- Structural Content (SC)
- Structural Similarity Index Metric (SSIM)

II. IMAGE FUSION ALGORITHMS

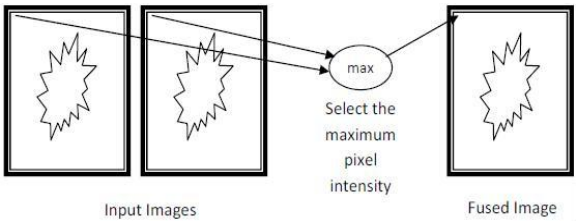
Image Fusion method can be divided into two groups. 1. Spatial domain fusion and 2. Transform domain fusion.

Spatial domain fusion directly deals with pixels of input images [4]. The fusion methods such as simple maximum, simple minimum, average and principal component analysis (PCA) fall under spatial domain approaches.

a) Select Maximum Method: In this method, the resultant fused image is obtained by selecting the maximum intensity of corresponding pixels from both the input images.

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} maxA(i,j)B(i,j) \qquad (1)$$

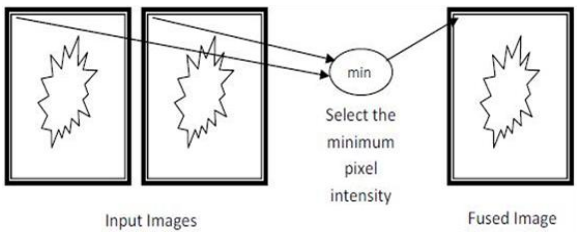
where A (i , j) and B (i , j) are two input images and F(i ,j) is fused image.



b) Select Minimum Method: In this method, the resultant fused image is obtained by selecting the minimum intensity of corresponding pixels from both the input images**.**

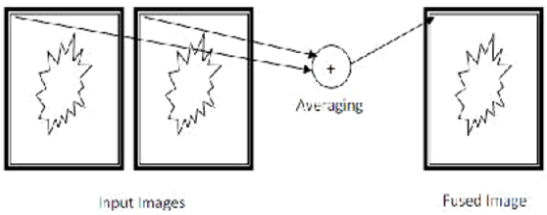
$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} minA(i,j)B(i,j) \qquad (2)$$

where A (i , j) and B (i , j) are two input images and F(i ,j) is fused image.

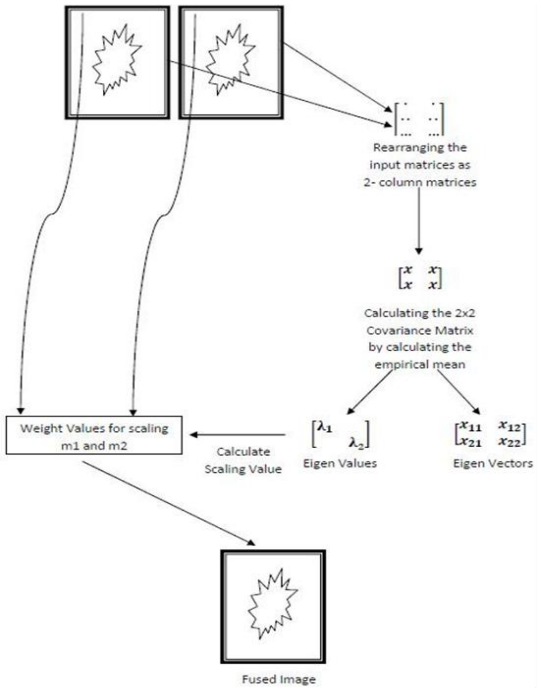


c) Simple Average Method: In this method the resultant fused image is obtained by taking the average intensity of corresponding pixels from both the input images.

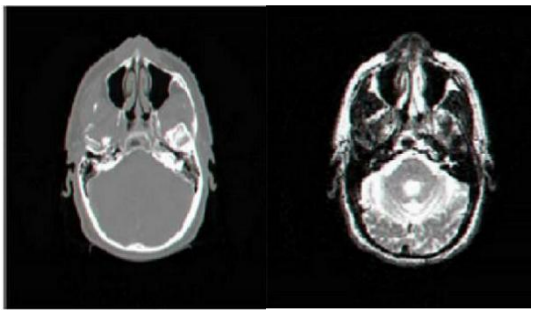
$$F(i,j) = \{A(i,j) + B(i,j)\}/2 \qquad (3)$$



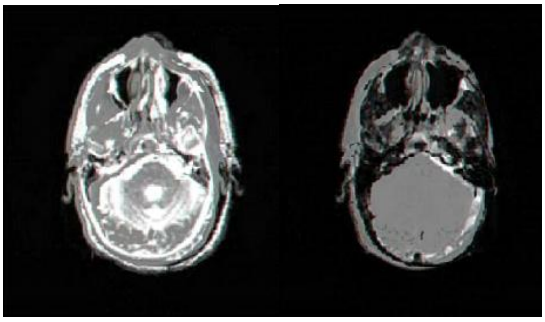
d) Principal Component Analysis (PCA): Principal Component Analysis is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis. It is the simplest and most useful of the true Eigen vector based multivariate analyses, because itsoperation is to reveal the internal structure of data in an unbiased way. It is mostly used as a tool in exploratory data analysis and for making predictive models [6] [7].



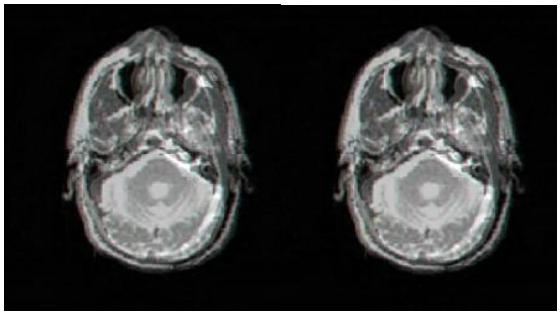
III. FUSION RESULTS



Source Images
a)CT Image b)MRI Image



c)Maximum Method d)Minimum Method



e)Average Method f)PCA Method

IV. IMAGE QUALITY METRICS

The general requirement of an image fusion process is to preserve all valid and usefull information from the source images, while at the same time it should not introduce any distortion in resultant fused image [9] [10].

a) Mean Square Error (MSE): Mean square error is one of the most commonly used error projection method where, the error value is the value difference between the actual data and the resultant data.**b) Peak Signal to Noise Ratio (PSNR):** Defined as log of the ratio between the square of the peak value to the Mean Square Error multiplied to the value 10. This basically projects the ratio of the highest possible value of the data to the error obtained in the data.

c) Average Difference (AD): Average Difference, as explained by the term itself, is the average value of the differencebetween the actual/ideal data and the obtained/resultant data.

d) Structural Content (SC): Here the ratio between the content of the both the expected and the obtained data. Practically, it is the ratio between the net sum of the square of the expected data and the net sum of square of the obtained data.

e) Normalized Cross Correlation (NCC): Here a cross correlation is performed between the expected data and the obtained data and normalized with respect to the expected data.

f) Maximum Difference (MD): Maximum Difference is a very simple metric that gives us the information of the largest of thecorresponding pixel error.

g) Normalized Absolute Error (NAE): This is a metric where the error value is normalized with respect to the expected or the perfect data. That is, the net sum ratio between the error values and the perfect values is calculated. The net sum of the error value which is the difference between the expected values and the actual obtained values is divided by the net sum of the expected values.

i) Laplacian Mean Square Error (LMSE): Laplacian Mean Square Error, as explained by the term, is the normal mean square errorcalculation. But the difference here is that the mean square error is calculated not based on the expected and obtained data but basedon the Laplacian value of the same.

j) Structural Similarity Index Metric (SSIM): The Structural Similarity Index measures the similarity between two images.

V. CONCLUSION

The four image fusion techniques were implemented using MATLAB 2016. Thefusion was performed on a set of input pair of images. The fused images were verified for their quality based on a perfect image ineach of the sets. A set of 9 image metrics were developed to assess the fused image quality.

In the total of four image fusion techniques, three very basic fusion techniques wereAveraging Method, Maximum Selection Method and Minimum Selection Method and a Principal Component Analysis (PCA) Method. By the means of the 9 image metrics developed - MSE, PSNR,SC, NCC, AD, MD, NAE, LMSE and SSIM, the Principal Component Method was assessed as the fusion algorithm producing a fused image of superior quality compared to the other three.

The project does hold scope for further advancements as a lot of research ishappening in the field. The following are some proposed practical advancements possible in the project:

- Multi Wavelets based image fusion can be performed to achieve a better image fusion quality.
- The image fusion quality has been assessed based on optical image sets with a perfect image.
- Image Registration has not been incorporated in the project. Image Registration /Image Alignment will certainly enhance the efficiency of the project as vast set of even unregistered images can be considered as set of input images. It would also help in possibility of more set of sample test/perfect images made available for assessing the image fusion algorithms.

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