

Image Fusion For Medical Image Retrieval

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ABSTRACT:

In medical imaging, various modalities provide different features of the human body because they use different physical principles of imaging. CT and MRI images with high spatial resolution provide the anatomical details, while PET and SPECT show the biochemical and physiological information but their spatial resolutions are not good enough. So it is very useful and important to combine images from multi-modality scanning such that the resulting image can provide both functional and anatomical information with high spatial resolution. In this paper we present a wavelet-based image fusion algorithm. The images to be fused are firstly decomposed into high frequency and low frequency bands. We select four groups of images to simulate, and compare our simulation results with the pixel addition, weighted averaging method and wavelet method based on min-max and subtraction based fusion rule. Then, the low and high frequency components are combined by using different fusion rules. Finally, the fused image is constructed by inverse wavelet transform. The various objective and subjective evaluation metrics and Quality are calculated to compare the results. The wavelet based fusion methods using different fusion rules is compared both subjectively as well as objectively. The experimental results show that the pixel minimum method is giving the better results in respect of MSE, SNR and using edge based quality metrics addition method observed to be better in preserving the edge information. One Image fusion method can be perfect for one particular application but may not for another application. So it depends on which information to extract, enhance, and reconstruct or retrieve to use the particular fusion method.

KEYWORDS: Computed Tomography (CT), DWT (Discrete Wavelet Transform), Image fusion, MRI (Magnetic Resonance imaging), Quality.

I. INTRODUCTION

In health care domain there are many research projects. The medical system is under many pressuring factors to offer the highest services, with efficiency, in the conditions of a growing population. To offer a real support for diagnosis, images have to be processed with different algorithms, for a better accuracy. A fusion based on transforms has some advantages over other simple methods, like: energy compaction, larger SNR, reduced features, etc. The transform coefficients are representative for image pixels. Clinical investigations are based more and more on medical imaging and physicians are faced very often with the difficulty of integrating the great amount of data. The specialists have to visualize and compare images from different medical modalities and to correlate the observed information with the clinical and auxiliary data. A fusion of multimodal images can be very useful for clinical applications such as diagnosis, modeling of the human body or treatment planning. Fusion of images taken at different resolutions, intensity and by different techniques helps physicians to extract the features that may not be normally visible in a single image by different modalities. The usage of fusion in radiotherapy and skull surgery. Here, the information provided by magnetic resonance imaging (MRI) and X-ray computed tomography (CT) is complementary. CT provides best information about denser tissue and MRI offers best information on soft tissue. Normal and pathological soft tissues are better visualized by MRI, while the structure of tissue bone is better visualized by CT. The composite image, not only provides salient information from both images simultaneously, but also reveals the relative position of soft tissue with respect to the bone structure.

Fusion of images taken at different resolutions, intensity and by different techniques helps physicians to extract the features that may not be normally visible in a single image by different modalities. This work aims at the fusion of registered CT and MRI Images.

This fused image can significantly benefit medical diagnosis and also the further image processing such as, visualization (colorization), segmentation, classification and computer-aided diagnosis (CAD). Especially in image fusion the edge preservation is important in obtaining the complementary details of the input images. As an edge representation in Curvelet is better, Curvelet based image fusion is best suited for medical images. The images used here are gray scale CT and MRI images. However, the images of other modalities (like PET, SPECT, and X-ray etc.) with their true color nature may also be fused using the same methods. [1] In a wavelet-based image fusion algorithm the images to be fused are firstly decomposed into high frequency and low frequency bands. Then, the low frequency components are combined with the maximum energy rule and high frequency components are combined with variance rule. Finally, the fused image is constructed by inverse wavelet transform. They have selected four groups of images to simulate, and compare their simulation results with the pixel averaging method and most common wavelet method based on mean-max fusion rule. In the process of fusion they gave fusion rule based on energy and variance, which effectively conserved the energy of source images and avoided the loss of useful information. Comparing with the most common algorithm, the proposed fusion method gives improved visual effect of fused image and also improved objective parameter such as, entropy, standard deviation and RMSE.

[3] Techniques for image fusion like, primitive fusion (Averaging Method, Select Maximum, and Select Minimum), Discrete Wavelet transform based fusion, Principal component analysis (PCA) based fusion etc. are proposed. Comparison of all the techniques concludes the better approach for its future research. The Wavelet transforms is the very good technique for the image fusion provides a high quality spectral content. But a good fused image has both qualities so the combination of DWT & spatial domain fusion method (like PCA) fusion algorithm improves the performance as compared to use of individual DWT and PCA algorithm. Finally, this review concludes that image fusion algorithm based on a combination of DWT and PCA with morphological processing will improve the image fusion quality and may be the future trend of research regarding image fusion. [4].

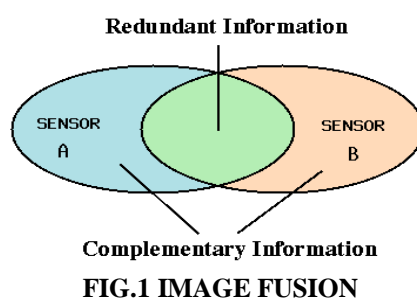
A novel wavelet based technique for image fusion which is developed by taking into account the physical meaning of the wavelet coefficients. After the images to be fused are decomposed by the wavelet transform, the coefficients of higher frequency bands and low frequency band are performed with new fusion schemes: the former is selected by a variety based scheme and the latter is selected by an edge based scheme. The performance of the proposed method is quantitatively compared with those of pixel averaging method and wavelet based methods. Experimental results clearly demonstrate the feasibility and effectiveness of the proposed method. [5].

The basic fusion algorithms, the pyramid based algorithms and the basic DWT algorithms are developed. The objective of the work was to assess the wide range of algorithms together, which is not found in the literature. The fused images were assessed using Structural Similarity Image Metric (SSIM), Laplacian Mean Squared Error along with seven other simple image quality metrics that helped us measure the various image features; Pareto Optimization method is used to figure out the algorithm that consistently had the image quality metrics produce the best readings Out of total eleven image fusion techniques were implemented, three very basic fusion techniques were Averaging Method, Maximum Selection Method and Minimum Selection Method, five pyramidal methods were FSD Pyramid, Laplacian Pyramid, Gradient Pyramid, Ratio Pyramid and Morphological Pyramid Methods and two of basic wavelet methods were Haar Wavelet and DBSS(2,2) Wavelet Methods. A set of nine image metrics were implemented to assess the fused image quality. The fused images of each set were also assessed based on their visual quality by ten respondents selected in random. The quality assessment based on the image metrics developed and visual perception was compared to assess the credibility of the image metrics. The readings produced by the 9 image metrics developed - MSE, PSNR, SC, NCC, AD, MD, NAE, LMSE and SSIM, were used to assess the best fusion algorithm (in terms of the quality of the fused images) using Pareto optimality method. DWT with Haar based fusion method was assessed best. [6].

Wavelet-based schemes perform better than standard schemes, particularly in terms of minimizing color distortion. Schemes that combine standard methods with wavelet transforms produce superior results than either standard methods or simple wavelet-based methods alone. The results from wavelet-based methods can also be improved by applying more sophisticated models for injecting detail information; however, these schemes often have greater set-up requirements. The simplest wavelet-based fusion scheme tends to produce better results than standard Fusion schemes such as IHS and PCA, further improvement is evident with more sophisticated wavelet based fusion schemes. The drawback is that there is greater computational complexity and often parameters must be set up before the fusion scheme can be applied.[7].

Authors have done the analysis of results of image fusion methods. As per their analysis fused image using pixel-based technique has good contrast and it works well for input images with similar levels of contrast. When input images have drastically different contrasts, pixel base fusion tends to take most data from the brighter image. Fused image has lower contrast in case of average based technique and it works well for input images with different levels of contrast. The wavelet based technique has very good contrast. In real applications, information from different sensors is not likely to be treated equally important. They have proposed a pixel based system that simultaneously compute image pixel intensity value taken from set of images and compared both and find the best value to be considered for the final fuse image. But problem of blurs is with this method and recovers the original undistorted image, all in high resolution, without any prior knowledge of the blurs and original image. Wavelet based method for image fusion gives better results which removes the limitation of pixel based image fusion method[8].

Image fusion based on wavelet decomposition, i.e. a multiresolution image fusion approach can fuse images with the same or different resolution level, i.e. range sensing, visual CCD, infrared, thermal or medical. A comparative analysis is carried out against classical existing strategies, including those of multiresolution. When the images are smooth, without abrupt intensity changes, the wavelets work appropriately, improving the results of the mentioned classical methods. This has been verified with smooth images and also with the medical images, where no significant changes are present. [9].



II. WAVELET BASED IMAGE FUSION

Wavelet theory is one of the most modern areas of mathematics. Wavelet transforms and other multiscale analysis functions have been used for compact signal and image representations in de-noising, compression and feature detection processing problems for about twenty years. Numerous research works have proven that space-frequency and space-scale expansions with this family of analysis functions provided a very efficient framework for signal or image data. The wavelet transform itself offers great design flexibility. Basis selection, spatial-frequency tiling, and various wavelet threshold strategies can be optimized for best adaptation to a processing application, data characteristics and feature of interest. Wavelet transformation, originally a mathematical tool for signal processing, is now popular in the field of image fusion. Recently, many image fusion methods based on wavelet transformation have been published. The wavelets used in image fusion can be categorized into three general classes: Orthogonal, Biorthogonal and Nonorthogonal. Although these wavelets share some common properties, each wavelet leads to unique image decomposition and a reconstruction method which leads to differences among wavelet fusion methods[10].

2.1. Wavelets for image fusion

1. It is a multiscale (multiresolution) approach well suited to manage the different image resolutions. Multiscale information can be useful in a number of image processing applications including the image fusion.
2. The discrete wavelets transform (DWT) allows the image decomposition in different kinds of coefficients preserving the image information.
3. Such coefficients coming from different images can be appropriately combined to obtain new coefficients, so that the information in the original images is collected appropriately.
4. Once the coefficients are merged, then the fused image is achieved through the inverse discrete wavelets transform (IDWT), where the information in the merged coefficients is also preserved. The key step in image fusion based on wavelets is that of coefficient combination, namely, the process of merge the coefficients in an appropriate way in order to obtain the best quality in the fused image. This can be achieved by a set of strategies. The most simple is to take the average of the coefficients to be merged, but there are other merging strategies with better performances. [16]

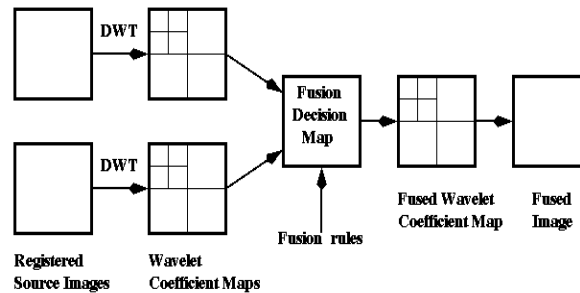


Fig.1 Fusion process using multi level image decomposition.

2.2. Discrete wavelet transform (DWT)

Fusion based on transforms has some advantages over other simple methods, like: energy compaction, Larger SNR, Reduced features, etc. The transform coefficients are representative for image pixels. Wavelets are used for time frequency localization, and perform multi-scale and multi resolution operations. Discrete wavelet transform (DWT), transforms a discrete time signal to a discrete wavelet representation. It converts an input series x_0, x_1, \dots, x_m , into one high-pass wavelet coefficient series and one low-pass wavelet coefficient series of length $n/2$ each given by

$$H_i = \sum_{m=0}^{k-1} x_{2i-m} * S_m(Z) \quad \dots\dots\dots (1)$$

$$L_i = \sum_{m=0}^{k-1} x_{2i-m} * t_m(Z) \quad \dots\dots\dots (2)$$

$sm(z)$ and $tm(z)$ are called wavelet filters, k is the length of the filter, and $i=0, \dots, [n/2]-1$. In practice, such a transformation will be applied recursively on the low-pass series until the desired number of iterations is reached.

2.3. The advantages of haar wavelet transform as follows

Best performance in terms of computation time.

1. Computation speed is high.
2. Simplicity
3. HWT is efficient compression method
4. It is memory efficient, since it can be calculated in place without a temporary array

III. IMAGE FUSION RULE

Fusion rules determine how the source transforms will be combined:

- Fusion rules may be application dependent
 - Fusion rules can be the same for all sub-bands or dependent on which sub-band is being fused
- There are two basic steps to determine the rules:
- compute salience measures corresponding to the individual source Transforms
 - decide how to combine the coefficients after comparing the salience measures (selection or averaging)
 - The main issue in wavelet fusion technique is the selection of decomposition

Different modalities can be fused using the Fusion rule. Fusion selection rule includes choosing the salient features of the image inputs. Higher absolute values of coefficients correspond to features such as edges or singularities.

OBJECTIVES OF THE RESEARCH WORK

1. Using haar wavelet filter to preserve the edges and details of the images
2. To efficiently reduce noise in medical images,
3. Comparison of various wavelet based pixel image fusion method to achieve minimum Mean Square Error value and maximum Signal to Noise Ratio value
4. Results of various fusion techniques are extracted and then these results are again compared with other Image Fusion methods and find the best suited method for medical applications.

IV. PIXEL LEVEL FUSION

Pixel-by-pixel fusion techniques include the basic arithmetic operations, logic operations and probabilistic operations as well as slightly more complicated mathematical operations. The image values include pixel gray-levels, feature map values and decision map labels. Although more sophisticated techniques are available, the simple pixel operations are still widely used in many image fusion applications. We consider fusion techniques which rely on simple pixel operations on the input image values. We assume the input images are spatially and temporally aligned, semantically equivalent and radiometrically calibrated. The image fusion of K input images I_1, I_2, \dots, I_K using a simple arithmetic addition operator.

4.1. LINEAR FUSION RULE: ADDITION

Addition which is probably the simplest fusion operation. It works by estimating the average intensity value of the input images $I_k, \{k=1, 2, \dots, K\}$, on a pixel-by-pixel basis. If $I(m, n)$ denotes the fused image at the pixel (m, n) , then

$$I(m, n) = \frac{1}{K} \sum_{k=1}^K I_k(m, n) \quad \dots\dots\dots(1)$$

4.2. Nonlinear Fusion Rule: Nonlinear Methods

Another simple approach to image fusion is to build the fused image by the application of a simple nonlinear operator such as max or min. If in all input images the bright objects are of interest, a good choice is to compute the fused image by a pixel-by-pixel application of the maximum operator.

4.2.1. Maximum fusion rule:

$$I(m, n) = \max(I_1, I_2, \dots, I_k); \quad \dots\dots\dots(2)$$

4.2.2. Minimum fusion rule:

$$I(m, n) = \min(I_1, I_2, \dots, I_k); \quad \dots\dots\dots(3)$$

Image fusion aims at the integration of various complementary image data into a single, new image with the best possible quality. The term "quality" depends on the demands of the specific application, which is usually related to its usefulness for human visual perception, computer vision or further processing.

V. OBJECTIVE EVALUATION USING STATISTICAL CHARACTERISTICS

Some of the statistical measures are Signal to Noise Ratio (SNR), Peak signal to noise ratio (PSNR) and Mean square error (MSE). These are commonly used measures in assessing image fusion techniques that consider an image as a special type of signal. The quality of signal is often expressed quantitatively with the signal-to-noise ratio defined as

$$SNR = 10 \log_{10} \frac{\sum_{m=1}^{S_1} \sum_{n=1}^{S_2} z(m, n)^2}{\sum_{m=1}^{S_1} \sum_{n=1}^{S_2} [z(m, n) - o(m, n)]^2} \quad \dots\dots\dots(4)$$

Where $z(m, n)$ and $o(m, n)$ denote the intensity of the pixel of the estimated and original image respectively at location (m, n) . The size of the image is $S_1 \times S_2$. High values of SNR show that the error of the estimation is small and therefore, among various image fusion methods the ones that exhibits higher SNR's can be considered of better performance. The PSNR and MSE are measures similar to the SNR defined as

$$PSNR = 10 \log_{10} \frac{255^2}{\sum_{m=1}^{S_1} \sum_{n=1}^{S_2} [z(m, n) - o(m, n)]^2} \quad \dots\dots\dots(5)$$

$$MSE = \frac{\sum_{m=1}^{S_1} \sum_{n=1}^{S_2} [z(m, n) - o(m, n)]^2}{255^2} \quad \dots\dots\dots(6)$$

When assessing the performance of an image fusion technique using the above mentioned measurements, we require knowledge of the original image (ground truth or full-referenced). For the reason these measurements can be used only with synthetic (simulated) data. The above measurements exhibit the drawback of providing a global idea regarding the quality of an image. In cases where the fused image exhibits artifacts concentrated within a small area, these measurements can still provide an acceptable value even if the image is visually unacceptable.

VI. OBJECTIVE EVALUATION BASED ON IMPORTANT FEATURES

One goal of image fusion is to integrate complementary information from multiple sources so that the new images are more suitable for the purpose of human visual perception and computer processing. Therefore, a measure should estimate how much information is obtained from the input images.

Different quality measures

1. LABF: Fusion loss
2. NABF: fusion artifacts or fusion noise
3. QABFc common information in fused image.
4. QdABF: total fusion gain.
5. Qc common information component compute the
6. QABF :information contribution of
7. QAFo information contribution of A into F
8. QBFo information contribution of B into F
9. Qd = abs(QAF - QBF);
10. Qc = (QAF+QBF-Qd)/2 : common information component
11. QdAF = QAF - Qc; QdBF = QBF - Qc;

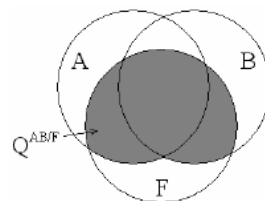


Figure 6: Graphical representation of the image information fusion process

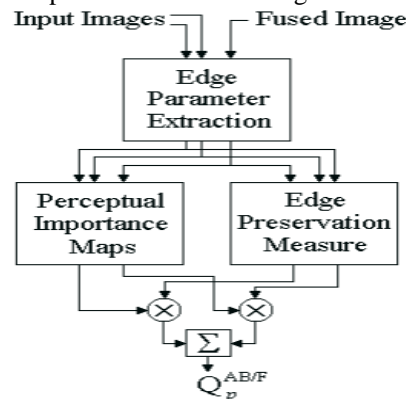


Figure 7: Basic structure of the objective image fusion performance measure

5. QUALITY METRICS IMPLEMENTED

- a) Statistical measures: SNR, PSNR, MSE
- b) Edge based quality measures: $Q^{AB/F}$, $Q_c^{AB/F}$, $Q_d^{AB/F}$, and $L^{AB/F}$
- c) UIQI based quality measure: Q_o

For UIQI based quality measures the following specifications have been taken:

- 1) Window of all ones of size 8X8 is taken.
- 2) Contrast is taken as the saliency for the input images. Variance corresponds to the contrast. So variance is calculated for every sliding window.

$$Q_o = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2xy}{x^2 + y^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2} \dots\dots\dots(7)$$

Wang and Bovik refer to Q_o as an *image quality index* and use it to quantify the structural distortion between images x and y , one of them being the reference image and the other the distorted one. In fact, the value $Q_o = Q_o(x, y)$ is a measure for the similarity of images x and y and takes values between -1 and 1. Note that the first component in eqn.(7) is the correlation coefficient between x and y . The second component corresponds to a kind of average luminance distortion and it has a dynamic range of [0, 1] (assuming nonnegative mean values). The third factor in eqn.(7) measures a contrast distortion and its range is also [0, 1]. The maximum value $Q_o = 1$ is achieved when x and y are identical.

Common information in F (fused image):

$$Q_c^{AB/F} = \frac{\sum_{r,n,m} Q_{r,n,m}^c (w_{r,n,m}^A + w_{r,n,m}^B)}{\sum_{r,n,m} [w_{r,n,m}^A + w_{r,n,m}^B]} \dots\dots\dots(8)$$

Fusion loss

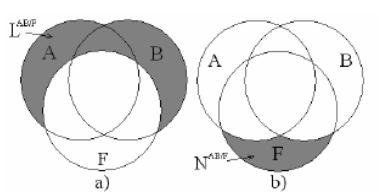


Figure 8: a) Fusion information loss L^{AB/F} and b) Fusion artifacts, N^{AB/F}

RESULTS BASED ON MEDICAL IMAGE FUSION

Table 9.1

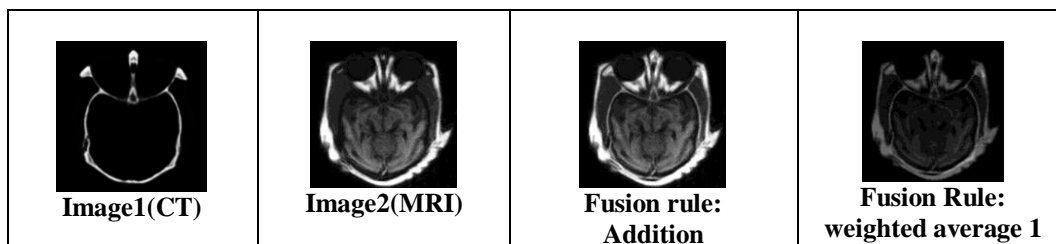
FUSION RULE	Mean	SNR	MSE	PSNR (db)	RMSE	Std.Dev.
Addition	59.62	0.738	6142.88	10.281	78.37	60.58
weighted avg1 (0.6 *CT + 0.4*MRI)	25.07	1.476	954.975	18.364	30.90	26.50
weighted avg2 (0.4 *CT + 0.6*MRI)	34.84	0.661	2152.30	14.835	46.39	35.68
Subtraction (max pix –min. pixel)	52.57	0.120	5808.20	10.524	76.21	56.22
Pixel Min	4.66	1.809	139.48	26.719	11.81	13.71
Pixel Max	56.18	0.475	5815.22	10.519	76.25	57.27

Table 9.2

FUSION RULE	QABF	QABFC	QdABF	NAB	Quality index Q0	LABF
Addition	0.7941	0.0206	0.773	0	0.0696	0.131
weighted avg1	0.2567	0.0448	0.211	0	0.1497	0.738
weighted avg2	0.5698	0.0480	0.521	0	0.1182	0.422
Subtraction	0.5850	0.02662	0.558	0	0.1089	0.294
Min	0.1266	0.0455	0.081	0	0.4401	0.855
Max	0.7461	0.0488	0.697	0	0.0945	0.199

Table 9.3

FUSION RULE	Joint histogram _medA	Similarity _medA	RMSE_wrt _medA	Correlation _medA	Mutual information _medA	Similarity _medB
Add	8.031	0.089	14.80	0.363	0.442	0.899
wtd avg1	6.905	0.181	11.66	0.506	0.452	0.550
wtd avg2	7.464	0.106	12.77	0.277	0.373	0.800
Sub	8.056	0.032	14.07	0.006	0.322	0.827
Min	3.891	0.799	2.88	0.835	0.604	0.064
Max	8.029	0.082	14.32	0.204	0.377	0.909



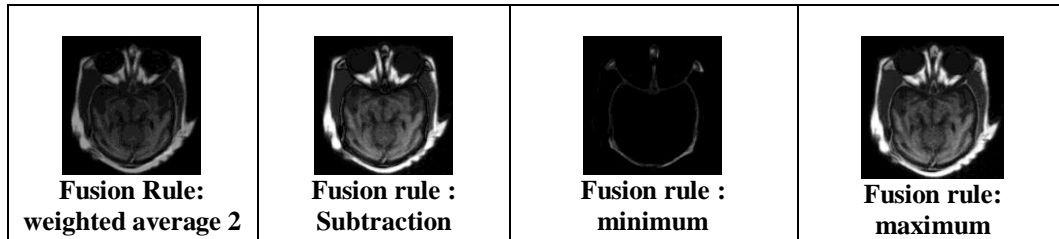
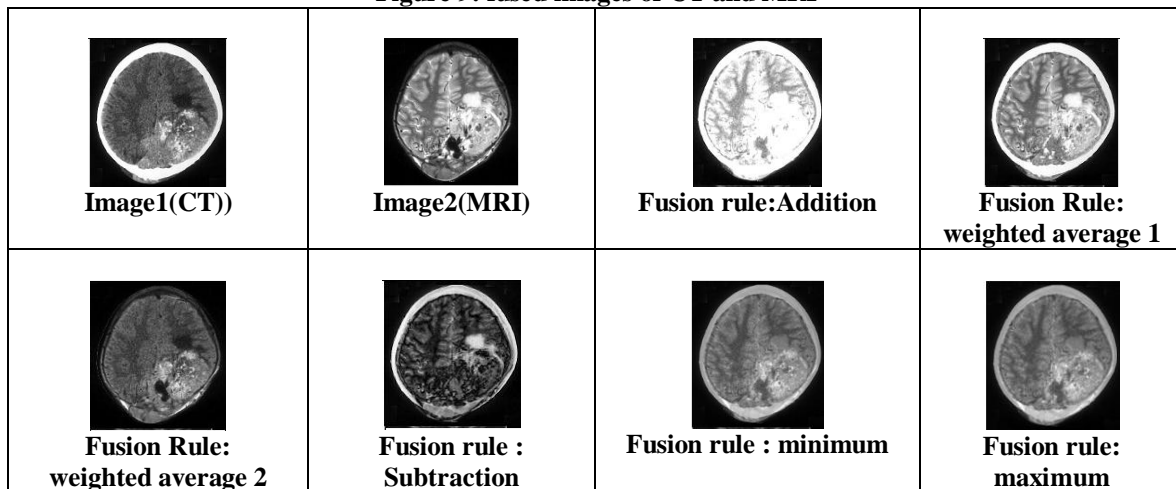


Figure 9: fused images of CT and MRI



VII. DISCUSSIONS AND CONCLUSION

The wavelet based fusion method using different fusion rules is proposed and it is applied on the CT and MRI images of the human brain. We have used different sets of the registered multimodal brain images. It is observed that minimum pixel replacement method is giving the better results as compared to other methods as the noise is much reduced in minimum method. Contrast of the images is much improved in the coefficient addition method. Also if we change the weights on the both modality we are getting different results. Contrast improves if we are giving more weight to MRI image (i.e. soft tissue structure visible more clearly). Error observed is less when more weight is given to CT. Any artifacts present in the fusion process may be considered as information. As medical images are low contrast images the information in all the parts (intensity areas) is equally important. We have also assess the fused images using edge based quality parameters also to observe how much edge information is preserved in the fused image. Edge is more efficiently preserved in the coefficient addition method of fusion with less information loss. The information retrieval is of much importance in medical application. The information in the soft tissue and bony structure both are important in diagnosis of any canceral development or any fracture. Contrast of the images.

VIII. FUTURE SCOPE

In many important imaging applications, images exhibit edges and discontinuities across curves. In biological imagery, this occurs whenever two organs or tissue structures meet. Especially in image fusion the edge preservation is important in obtaining the complementary details of the input images. As edge representation in Curvelet is better as it enhancing the curved edges more efficiently whereas in wavelet it can enhance the linear edges better than curved edges, Curvelet based image fusion is best suited for medical images. [10]

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