THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Medical Image Fusion

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Abstract:
A novel approach for medical image fusion is presented, which is developed by taking into account the spectral and spatial characteristics of image. After the medical images to be fused are decomposed by the weighted technique, different-fusion schemes for combining the coefficients are proposed: coefficients in low-frequency band are selected with a visibility-based scheme, and coefficients in high-frequency bands are selected with a variance based method. The fused image is finally constructed by the inverse process with all composite coefficients. To quantitatively evaluate and prove the performance of the proposed method, series of experiments and comparisons with some existing fusion methods are carried out. Experimental results on real medical images indicate that the proposed method is effective and can get satisfactory fusion results.

Keywords*: Image fusion, spectral characteristics, spatial characteristics*

1. Introduction

Nowadays, with the rapid development in high-technology and modern instrumentations, medical imaging has become a vital component of a large number of applications, including diagnosis, research, and treatment. In order to support more accurate clinical information for physicians to deal with medical diagnosis and evaluation, multimodality medical images are needed, such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), and positron emission tomography (PET) images. These multimodality medical images usually provide complementary and occasionally conflicting information. For example, the CT image can provide dense structures like bones and implants with less distortion, but it cannot detect physiological changes, while the MR image can provide normal and pathological soft tissues information, but it cannot support the bones information. In this case, only one kind of image may not be sufficient to provide accurate clinical requirements for the physicians. Therefore, the fusion of the multimodal medical images is necessary and it has become a promising and very challenging research area in recent years[9].

An image (from Latin: imago) is an artifact that depicts or records visual perception, for example a two-dimensional picture, that has a similar appearance to some subject – usually a physical object or a person, thus providing a depiction of it. Images may be two-dimensional, such as a photograph, screen display, and as well as a three-dimensional, such as a statue or hologram. They may be captured by optical devices – such as cameras, mirrors, lenses, telescopes, microscopes, etc. and natural objects and phenomena, such as the human eye or water surfaces[11].

Image Processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image. Usually Image Processing system includes treating images as two dimensional signals while applying already set signal processing methods to them. It is among rapidly growing technologies today, with its applications in various aspects of a business. Image Processing forms core research area within engineering and computer science disciplines too[1].

Image processing basically includes the following three steps.

- Importing the image with optical scanner or by digital photography.
- Analyzing and manipulating the image which includes data compression and image enhancement and spotting patterns that are not to human eyes like satellite photographs.
- Output is the last stage in which result can be altered image or report that is based on image analysis.

Image Fusion is a process of combining information from a set of images into a single image, where the resultant fused image will be more informative and complete than any of the input images. Image fusion techniques can improve the quality and increase the application of these informaion.

One of the prominent method for image fusion is image fusion using guided filtering. Here in this method the input image is taken as the guidance image and at each stage the output is compared with the input image. It is a good method but have its own inefficiencies. Mainly the time required for this method is high.

So the method proposed here is image fusion using UWT(Unified weighted technique). It is an technique in which the image is converted into its gray scale and divided into several components. These components are obtained by taking different bands in the image.

The input provided here is two images of same scene taken by different methods. Since this is mainly applicable in medical field the input can be scanned image of skull one taken by MRI scan and another one by CT scan. Both the images are converted to gray scale. Different band levels of the image is taken. There are mainly LL, LH, HL, HH bands in an image. These are taken. So each input image is divided into four parts. Now again if better information is needed this is again divided into different levels based on this band levels. Then LL portion of first image is combined with LL portion of second image and so on. Finally they all are fused together to get an enhanced image.

Now in case of colour images the RGB planes of the image is taken and this method is applied. Since in medical images edges are given more importance this method is mainly used in medical field.

Multisensor data fusion has become a discipline which demands more general formal solutions to a number of application cases. Several situations in image processing require both high spatial and high spectral information in a single image. This is important in remote sensing. However, the instruments are not capable of providing such information either by design or because of observational constraints. One possible solution for this is image fusion. The fusion methods such as averaging, Brovey method, principal component analysis (PCA) and IHS based methods fall under spatial domain approaches. Another important spatial domain fusion method is the high pass filtering based technique. Here the high frequency details are injected into upsampled version of MS images. 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[9].

So to overcome these problems image fusion using UWT technique is proposed.

2. Related Works

2.1. Simple Average

The value of the pixel P (i, j) of each image is taken and added. This sum is then divided by 2 to obtain the average. The average value is assigned to the corresponding pixel of the output image. This is repeated for all pixel values.

$K(i, j) = \{X(i, j) + Y(i, j)\}/2$

Where X (i , j) and Y (i, j) are two input images[10]

2.1.1. Disadvantages

- Reduced contrast
- Some noises are introduced

2.2. Select Maximum

This algorithm chooses the in focus regions from each input image by choosing the greatest value for each pixel, resulting in highly focused output. The value of the pixel P (i, j) of each image is taken and compared to each other. The greatest pixel value is assigned to the corresponding pixel[10]

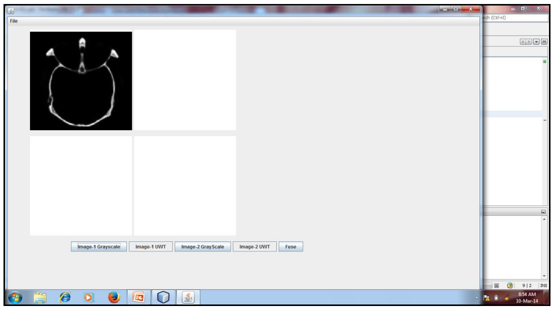
2.2.1. Disadvantages

- Ignores spectral information
- Produce spectral distortion

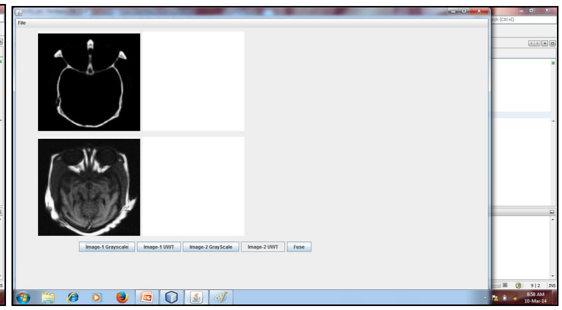
2.3. Discrete Wavelet Transform

- Step 1
  The images to be fused must be registered to assure that the corresponding pixels are aligned.
- Step 2
  These images are decomposed into wavelet transformed images, respectively, based on wavelet transformation. The transformed images with K-level decomposition will include one low-frequency portion (low-low band) and $3K$ high-frequency portions (low-high bands, high-low bands, and high-high bands)[10].
- Step 3
  The transform coefficients of different portions or bands are performed with a certain fusion rule[10].
- Step 4
  The fused image is constructed by performing an inverse wavelet transform based on the combined transform coefficients from Step 3[10].

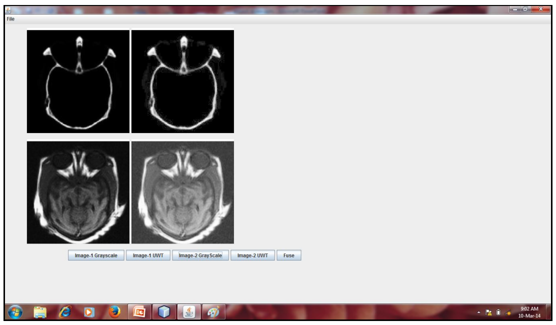
3. Design Overview



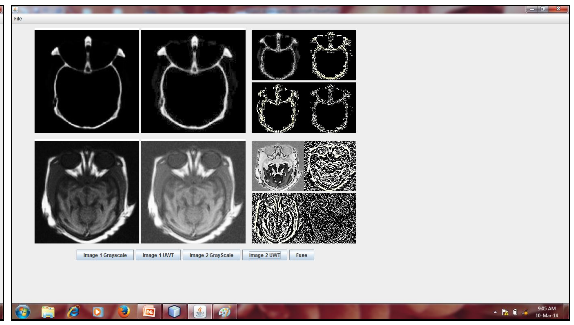
Input the first image



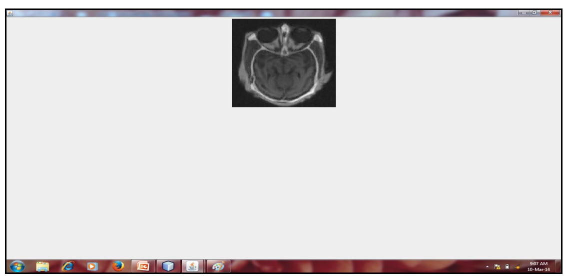
Input the second image



Converting both into grayscale



Dividing into different band levels



Fused image

4. Evaluation

The evaluation methods performed are:

(i) Standard Deviation

The standard deviation of an image with size of $M\times N$ is defined as

$$\hat{\sigma} = \left(\frac{1}{M\times N}\sum_{m=1}^{M}\sum_{n=1}^{N}\left(f(m,n)-\hat{\mu}\right)^2\right)^{1/2}, \quad (12)$$

where $f(m,n)$ is the pixel value of the fused image at the position (m,n), $\hat{\mu}$ is the mean value of the image. The standard deviation is the most common measure of statistical dispersion, which can be used to evaluate how widely spread the gray values in an image. So, the larger the standard deviation, the better the result[9,6].

(ii) Average Gradient

The average gradient of an image with size of $M\times N$ is defined as:

$$\mathrm{Avg} = \frac{1}{(M-1)\times(N-1)} \times\sum_{m=1}^{M-1}\sum_{n=1}^{N-1}\sqrt{\left[\left(\frac{\partial f(m,n)}{\partial m}\right)^2+\left(\frac{\partial f(m,n)}{\partial n}\right)^2\right]/2}, \quad (13)$$

where $f(m,n)$ is the same meaning as in the standard deviation. The average gradient reflects the clarity of the fused image. It is used to measure the spatial resolution of the fused image; that is, larger average gradient means a higher resolution.

(iii) Information Entropy

The formulation of the classical information entropy of an image is defined as

$$H = -\sum_{l=0}^{L-1} P_l \log_2 P_l, \quad (14)$$

where L is the number of gray level, and p_l equals the ratio between the number of pixels whose gray value is l $(0 \le l \le L-1)$ and the total pixel number contained in the image. The information entropy measures the richness of information in an image. Thus, the higher the entropy, the better the performance.

(iv) Cross Entropy (CE)

The cross entropy is used to measure the difference between the source images and the fused image. Small value corresponds to good fusion result obtained:

$$CE = \sum_{l=0}^{L-1} p_l \log_2 \frac{p_l}{Q_l}, \quad (15)$$

where p_l and Q_l denote the gray level histogram of the source image and fused image, respectively[9,6].

5. Throughput

It can be observed that the values of several quality indices such as the standard deviation, average gradient, and information entropy of the proposed method are larger than those of pixel averaging, gradient pyramid, and DWT methods. For instance, the average gradient of the proposed method is 4.5005, while the corresponding values of other three methods are 3.8985, 3.2708, and 3.7343, respectively. These three largest values presented here can indicate that with the proposed method the fused image can get higher spatial resolution and retain much more image information. By comparison, it can be seen that the cross entropy value of the proposed method is the smallest in the four methods. This means that with the proposed method the fused images have less difference to the source images than those of other three methods[9].

6. Conclusion

The fusion of multimodal medical images plays an important role in many medical applications since they can support more accurate information than any individual source image. This paper presents a novel weighted approach for medical image fusion. . The performance of the proposed method is compared with some existing fusion approaches. Experimental results show that the proposed method can preserve more useful information in the fused image with less difference to the source images.

7. References

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