Image Fusion in Remote Sensing Using Wavelet Transform

Mr. Sagar B. Girawale, Miss. Sujata B. Girawale

Abstract—The fusion of images is the process of combining two or more images into a single image retaining important features from each. Fusion is an important technique within many disparate fields such as remote sensing, robotics and medical applications. Wavelet based fusion techniques have been reasonably effective in combining perceptually important image features. The successful fusion of images acquired from different modalities or instruments is of great importance in many applications, such as medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. With 2D imaging and image processing becoming widely used, there is a growing need for new 2-D image fusion algorithms capable of combining 2D multimodality or multisource images. Such algorithms can be used in areas such as 2D e.g. fusion of images in Target tracking system, Synthetic Aperture Radar (SAR) etc. In case of target tracking system the time is the very important factor. So we take time as a comparison factor to compare different methods which we implement. In order to improve the efficiency of the project, Elapsed time for the fusion to run is being formulated.

Index Terms—Image fusion, remote sensing, DWT and types of wavelet, inverse DWT.

I. INTRODUCTION

Image fusion is the process that combines information from multiple images of the same scene. These images may be captured from different sensors, acquired at different times, or having different spatial and spectral characteristics. The object of the image fusion is to retain the most desirable characteristics of each image. With the availability of multisensor data in many fields, image fusion has been receiving increasing attention in the researches for a wide spectrum of applications. The main application of image fusion is merging the gray-level high-resolution panchromatic image and the colored low-resolution multispectral image. Standard fusion methods perform well spatially but usually introduce spectral distortion. To overcome this problem, numerous multiscale transform based fusion schemes have been proposed. In this project, we focus on the fusion method based on the discrete wavelet transform (DWT), the most popular tool for image processing. Due to the numerous multiscale transform, different fusion rules have been proposed for different purpose and applications.

Image fusion methods

There are various methods that have been developed to perform image fusion. Some well-known image fusion methods are listed below [5-9].

(1) Intensity-hue-saturation (IHS) transform based fusion
(2) Principal component analysis (PCA) based fusion
(3) Arithmetic combinations
(4) Multiscale transform based fusion
(a) High-pass filtering method
(b) Pyramid method
(c) Wavelet transform
(i) Discrete wavelet transform (DWT)
(ii) Stationary wavelet transform
(iii) Dual tree discrete wavelet transform
   (iv) Lifting wavelet transform
(5) Multi-wavelet transform
(6) Curvelet transform
(7) Total probability density fusion
(8) Biologically inspired information fusion

A. Satellite image fusion

Above methods are used for merging satellite images. In satellite imagery we can have two types of images,

1) Panchromatic Images-
The panchromatic (PAN) images has high spatial resolution but without color information.
2) Multispectral images-
In optical remote sensing fields, the multispectral (MS) image which contains color information is produced by three sensors covering the red, green and blue spectral wavelengths. Because of the trade-off imposed by the physical constraint between spatial and spectral resolutions, the MS image has poor spatial resolution.

(a) Multispectral low resolution input image, (contains color information is produced by three sensors covering the red, green and blue spectral wavelengths. & having poor spatial resolution.)
(b) Panchromatic high resolution input image (high spatial resolution but without color information.)

The standard merging methods are based on the transformation of the red–green–blue (RGB) multispectral channels into the intensity–hue–saturation components. Intensity refers to the total color brightness, hue refers to the dominant or average wavelength that contributes to a color, and saturation refers to the purity of a color relative to gray. With the standard methods the usual steps to perform are the following:

1. Register the low-resolution multispectral image to the same size as the high-resolution panchromatic image so that it is superimposed.
3. Modify the high-resolution panchromatic image to take into account the spectral differences with respect to the multispectral image, the different atmospheric and illumination conditions, etc.

Sagar B. Girawale doing his M.tech in Electronics Design Technology from National Institute of Electronics and Information Technology, Aurangabad in 2015
Sujata B. Girawale doing his M.tech in VLSI AND EMBEDDED SYSTEMS from G.H. RAISON, COE, CHAS, AHMEDNAGAR in 2015
4. Replace the intensity component with the panchromatic image, and perform the inverse transformation to obtain the merged RGB image with merged panchromatic information. This is usually performed by conventional histogram matching between two images. For this purpose, the histogram of the panchromatic image and the intensity component of the multispectral image is used as a reference to which we match the histogram of the panchromatic image.

The standard image fusion techniques, such as IHS based method, PCA based method and Brovey transform method operate under spatial domain. However, the spatial domain fusions may produce spectral degradation. This is particularly crucial in optical remote sensing if the images to fuse were not acquired at the same time. Therefore, compared with the ideal output of the fusion, these methods often produce poor result. Over the past decade, new approaches or improvements on the existing approaches are regularly being proposed to overcome the problems in the standard techniques. As multi-resolution analysis has become one of the most promising methods in image processing, the wavelet transform has become a very useful tool for image fusion. It has been found that wavelet-based fusion techniques outperform the standard fusion techniques in spatial and spectral quality, especially in minimizing color distortion. Schemes that combine the standard methods (HIS or PCA) with wavelet transforms produce superior results than either standard methods or simple wavelet-based methods alone. However, the tradeoff is higher complexity and cost.

1.3 BLOCK DIAGRAM

- Image from Sensor 1 → DWT
- Image from Sensor 2 → DWT
- Display fused image
- Inverse wavelet transform
- Choose coefficients as per fusion rule

1.4 BLOCK DIAGRAM DISCRPTION

1. IMAGES OF SAME SIZE

One of the main issues in image fusion is image alignment, which refers to pixel-by-pixel alignment of the images. For the resultant output image to be distinct and have a better visual interpretation than the mult-spectral and panchromatic images it is necessary to have both the MS & PAN images of same size. Same size of images also becomes a basic requirement for point to point correspondence between two pixel values. There have been many studies on pan sharpening and many, many algorithms have been developed. Pan sharpening algorithms depend on the input images being co-registered because all they perform operations on corresponding pixels in both images. They all do something with the multispectral pixel and the panchromatic pixels to create new pixels. If the images are not co-registered, the processing will use the wrong pixels, not the corresponding ones and the result will not look natural. For this purpose images should be registered.

2. DECOMPOSITION BY DWT:

![Fig.2 DECOMPOSITION BY DWT](image)

ยอด Discrete Wavelet Transform

In this project, we only introduce the discrete wavelet transform (DWT) based fusion schemes because DWT is the basic and simplest transform among numerous multiscale transform and other type of wavelet based fusion schemes are usually similar to the DWT fusion scheme. Therefore, we give a brief introduction of the DWT in this section.

Continuous wavelet transform (CWT):

Given a input signal x (t), the CWT of x (t) is defined as

\[ X_w(a,b) = \frac{1}{\sqrt{b}} \int_{-\infty}^{\infty} x(t) \psi\left(\frac{t-a}{b}\right) dt, \]

Where location factor a can be any real number, and scaling factor b can be positive real number. It is obvious that as b is larger, \( \psi \left(\frac{t-a}{b}\right) \) is more like a high-frequency signal, and thus output \( X_w \) (a, b) would represent the high-frequency component of x (t) after inner product with \( \psi \left(\frac{t-a}{b}\right) \). Also, larger b implies the window size of \( \psi \left(\frac{t-a}{b}\right) \) is smaller; that is, the location (time) resolution is smaller. Therefore, the location-scaling (time-frequency) resolution plane is as Fig. 2.

Discrete wavelet transform (DWT)

1. 1-D discrete wavelet transform

The DWT is similar to the DC-CWT except that the input signal is discrete. Therefore, the design rules for \( \psi \) (t), \( \varphi \) (t),

![Fig.3 Time-frequency resolution plane for wavelet transform](image)
g[k] and h[k] are similar as in the DC-CWT. The block diagram of the 1-D DWT is illustrated in Fig. 3

![Block diagram of the 1-D DWT](image)

**Fig.4**. The block diagram of the 1-D DWT

2. **Multi-level 1-D discrete wavelet transform**

Furthermore, the 1-D DWT confidents can be decomposed again using the 1-D DWT. This scheme is called multi-level 1-D DWT (see Fig. 4.3 for 2-level 1-D DWT).

![Block diagram of multi-level 1-D DWT](image)

**Fig.5**. Multi-level 1-D discrete wavelet transform

- **2-D discrete wavelet transform**

2-D DWT is very useful for image processing because the image data are discrete and the spatial-spectral resolution is dependent on the frequency. An example is shown in Fig. 4.5. The DWT has the property that the spatial resolution is small in low-frequency bands but large in high-frequency bands. The left-top sub-image (the band with lowest frequencies) has the smallest spatial resolution and represents the approximation information of the original image. Thus, the DWT is suitable for image compression. On the contrast, the other sub-images (the bands with high frequencies) show the detailed information of the original image. Therefore, these sub-images can be used for edge detection or corner detection.

- **2. EXTRACTION AND CONCATENATION OF COEFFICIENTS**:

After applying the simplified level decomposition using DWT the approximate and detailed coefficients are extracted. The detailed coefficients are further filtered to increase the luminance. After filtering of coefficients the approximate coefficients of multispectral image and detailed coefficients of panchromatic image concatenated. This is the step where actual image fusion take place.

- **4. INVERSE DWT (IDWT).**

The reconstruction process from the DWT coefficients is shown in the right part of Fig. 4.5, called inverse DWT (IDWT).

![Block diagrams of DWT and IDWT](image)

**Fig.6** the block diagrams of DWT and IDWT.

5. **DISPLAY FUSED IMAGE:**

After taking IDWT we get fused image, which is combination of PAN & MS images. Fused image is multispectral as well as high resolution image.

- **II. ALGORITHM:**

  - Start.
  - Read First And Second Image From Database.
  - Take Dwt On Both Images To Transform Into Wavelet Domain.
  - Choose Coefficients As Per Fusion Rules.
  - Take Inverse Wavelet Transform.
  - Display The Fused Image.
  - Stop.

- **III. TESTING**

1] Multispectral image:-

![Multispectral Image](image)

**Fig.7. Multispectral Image**

In optical remote sensing fields, the multispectral (MS) image which contains color information is produced by three sensors covering the red, green and blue spectral wavelengths. Because of the trade-off imposed by the physical constraint between spatial and spectral resolutions, the MS image has poor spatial resolution.

2] Panchromatic image:-
Image Fusion in Remote Sensing Using Wavelet Transform

The panchromatic (PAN) images has high spatial resolution but without color information.

IV. RESULT:-

(a) Fig.8. Panchromatic image

(b) Fig.9. (a) and (b) Before fusion

After fusion
(a) Result for HAAR wavelet:-

(b) Result for DB wavelet:-

(c) Result for SYMLET wavelet:-

V. APPLICATIONS

The main application of image fusion is merging the gray-level high-resolution panchromatic image and the colored low-resolution multispectral image. It technology has been used in several applications such as
- In medical application
- In Human perceptibility
- object detection & target recognition
- Observation of the environment
- Feature detection & Feature matching.
- Aerial and satellite imaging

VI. FUTURE SCOPE

Image fusion is expected to play a vital role in the future of Digital image processing. This paper mainly aims to implement fusion of 2-D images taken from remote sensors. However, this application can also be developed in future by integrating more number of sensors to fuse 3-d images using wavelet transform.

VII. CONCLUSION

We conclude that, wavelet transform leads to accuracy which is far improved and leads to extraction of maximum information as compared to other methods. And also Wavelet Transform shows better resemblance with HUMAN VISUAL SYSTEM. That is Wavelet transform fusion diagrams have been introduced as a convenient tool to visually describe different image fusion schemes

REFERENCES
[2] Shih-Gu Huang,” Wavelet for Image Fusion”, Graduate Institute of Communication Engineering & Department of Electrical Engineering, National Taiwan University,2011.


ABOUT THE AUTHORS

Mr. Sagar B. Girawale  did his B.E with honors’ (Electronics & Telecommunication from SVPM’S COE, MALEGAON(BK.), BARAMATI) in 2010-2014. Also he is doing M.tech in Electronics Design Technology from National Institute of Electronics and Information Technology, Aurangabad from August, 2014

Mr. Sujata B. Girawale  did his B.E with honors’ (Electronics & Telecommunication from SVPM’S COE, MALEGAON(BK.), BARAMATI) in 2010-2013. Also she is doing M.E in VLSI and EMBEDDED SYSTEMS from G.H. RAISONI, Chas, Ahmednagar