SAR and Optical Images Fusion Algorithm Based on Wavelet Transform

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Abstract - *Multisensor data fusion combines data and information from multiple sensors to achieve improved accuracies and better inference about the environment than single sensor alone. This paper presents a technique for fusing the Synthetic Aperture Radar (SAR) image and optical image at same scene using wavelet transform (WT) algorithm. Before fused the two images, a image registration affine transformation algorithm is presented at first, then selecting the maximized WT coefficient between SAR image and optical image, and inverse WT algorithm is executed using the selecting coefficient which described the typical target characters and presented the dominant information in their images. The results are given at last in figures formula and qualitative evaluation formula*.

Keywords: SAR image, Image Registration, Data Fusion. Wavelet Transform, Image Evaluation.

1 Introduction

People acquire more and more same scene images with the evolution of imaging technology. Images from many different sensors, such SAR, optical, IR have many applications, such as military applications, in surveillance and in medical diagnostics,etc.

Image fusion is a methodology concerned with the integrating of multiple images into a composite image that is more suitable for the purpose of human visual perception or computer processing tasks. Much research has been carried out on this topic since 1980s[1], especially in recent years, multisensor data fusion has been extensively investigated by researchers in a variety of science and engineering disciplines, such as automated target recognition[2,3],automatic landing guidance[4,5],remote sensing[6,7],monitoring of manufacturing processes[8],robotics[9],and medical applications[10].

As we seen previously, much work has been done based on different fusion algorithm and different application. Compared with others methods the proposal algorithm in this paper is based on the different characters of wavelet representation. As we know, an image is decomposed at different scales into a lower resolution image and three detail images , and reconstruction of the original image is accomplished by inverse wavelet transform with the decomposed image. The lower resolution image and detail images describe the different information, and we fused the different detail images , in which we chosed the principal information through inverse wavelet transformation algorithm, between SAR and optical images. The results have more precision and reliable evaluation with the single sensor image.

This paper is organized as follows. First there is a affine transformation algorithm which registrates the SAR image to the optical image . The goal of image registration is to establish the correspondence between two images and determine the geometric transformation that align the lower resolution SAR image with the optical image. Then a fusion algorithm using wavelet transformation and inverse wavelet transformation will be discussed in section III. Experimental results for SAR image and optical image fusion are given in Section IV. In Section V, a qualitative evaluation is presented about the fusion results. Fig. 1 describes our algorithm.

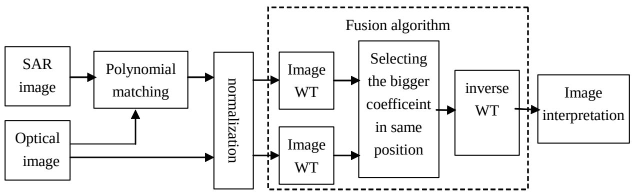

Fig.1 processing blocks for SAR image and optical image fusion algorithm

2 Images Registration

Images registration refers to the process of aligning images so that their details overlap accurately. And its result is achieved by rotating and translating the test image to align with the reference image. Therefore image registration is a vital first step in many sequence analysis applications, e.g., fusing multiple sensor data. Actually image registration can be regarded as a special case of image fusion.

Because of the influences about earth curvature and SAR moving platform's irregularity, the SAR image has some geometric deformabilties and there have some derivations in imaging direction compared with optical image. It is important that matching the SAR image into same plane with optical before the fusion processing. In our method we regard the SAR image as test image and optical image as reference image.

Affine transformation images registration algorithm is a commonly registration method which basic idea is consider that the image transform is a combined about shifting , zooming , affining, rotating and bending. It is achived by finding the affine transformation that maps a point set from one image into the same corresponding points in the other image. The transformation parameters can be obtained by selecting a set control points (x_i, y_i) $i = 1,...,n$ in one image that correspond to another points set (X_i, Y_i) $i = 1,...,n$ in other image,where $n \geq 3$. The registration is done by warping one image to the other using the transformation:

$$X_i = \sum_{j=0}^{n} \sum_{k=0}^{n-j} a_{j,k} x_i^{\,j} y_i^{\,k} \tag{1a}$$

$$Y_i = \sum_{j=0}^{n} \sum_{k=0}^{n-j} b_{j,k} x_i^{\,j} y_i^{\,k} \tag{1b}$$

where

n: the number of control points

$a_{j,k}, b_{j,k}$: matching coefficient

in practice we select the apparent correspondent points in both images by manually and find the solutions based on the least square method which demand the selecting points number must more than the unknown coefficients number and distribute homogeneously.

As the analysis previously, we make assumption that the apparent correspondent points are (X_i, Y_i) and (X_i', Y_i') in optical image and SAR image respectively, and $i = 0, \cdots, 7$ in our experiment. Then according to the described in (1a)(1b),we get the linear matching forms as follow:

$$X_i' = a_0 + a_1 X_i + a_2 Y_i \tag{2a}$$

$$Y_i' = b_0 + b_1 X_i + b_2 Y_i \tag{2b}$$

and rewrite it as matric forms :

$$X' = KA$$

$$Y' = KB$$

where

$$X' = \left[X_0' X_1' \cdots X_7'\right]^T$$

$$Y' = \left[Y_0' Y_1' \cdots Y_7'\right]^T$$

$$A = \left[a_0 a_1 a_2\right]^T$$

$$B = \left[b_0 b_1 b_2\right]^T$$

$$K = \begin{bmatrix} 1 & X_0 & Y_0 \\ \cdots & \cdots & \cdots \\ 1 & X_7 & Y_7 \end{bmatrix}$$

we can not get the solution since the matric K is not a square matric, but using the least square method and the matric theory ,we can solute the problem as follow:

$$A = \left(K^T K\right)^{-1} K^T X' \tag{3a}$$

$$B = \left(K^T K\right)^{-1} K^T Y' \tag{3b}$$

when we get the matching coefficient we could match the whole SAR image into optical image.

3 Wavelet Transformation and Images Fusion Algorithms

3.1 Discrete Wavelet Transform and Inverse Wavelet Transform

For discrete 2-dimensional image $I(m,n)$,the multiresolution expresses in wavelet form as $C_{m,n}^0$,we get the decomposition form as follow according to the multiresolution analysis:

$$\left.\begin{aligned} C_{m,n}^{j} &= \frac{1}{2}\sum_{k,l\in Z} \bar{h}_{k-2m}\bar{h}_{l-2n} C_{k,l}^{j-1} \\ d_{m,n}^{j1} &= \frac{1}{2}\sum_{k,l\in Z} \bar{h}_{k-2m}\bar{g}_{l-2n} C_{k,l}^{j-1} \\ d_{m,n}^{j2} &= \frac{1}{2}\sum_{k,l\in Z} \bar{g}_{k-2m}\bar{h}_{l-2n} C_{k,l}^{j-1} \\ d_{m,n}^{j3} &= \frac{1}{2}\sum_{k,l\in Z} \bar{g}_{k-2m}\bar{g}_{l-2n} C_{k,l}^{j-1} \end{aligned}\right\} \quad \begin{aligned} & j = 1,2,\cdots\cdots,N; \\ & m,n \in Z \end{aligned} \tag{4}$$

where

$\{C_{m,n}^{j}\}_{j=1}^{N}$ express the blur subimage , that is the low frequency subimage

$\{d_{m,n}^{j1}\}_{j=1}^{N}$ express the vertical direction subimage

$\{d_{m,n}^{j2}\}_{j=1}^{N}$ express the horizontal direction subimage

$\{d_{m,n}^{j3}\}_{j=1}^{N}$ express the diagonal direction subimage

from the view of filters the process can be presented as fig.2, $\downarrow 2$ express selection one between the two samples.

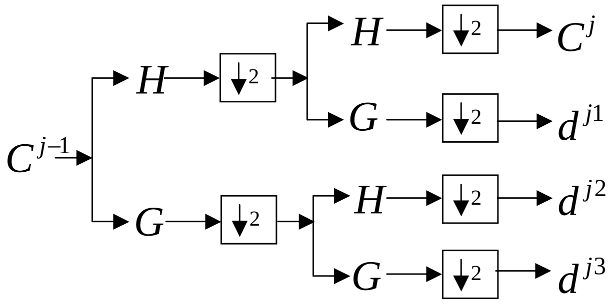

Fig.2 wavelet transform algorithm

corresponsively, the wavelet transform reconstruct is as fig.3 from the view of filters

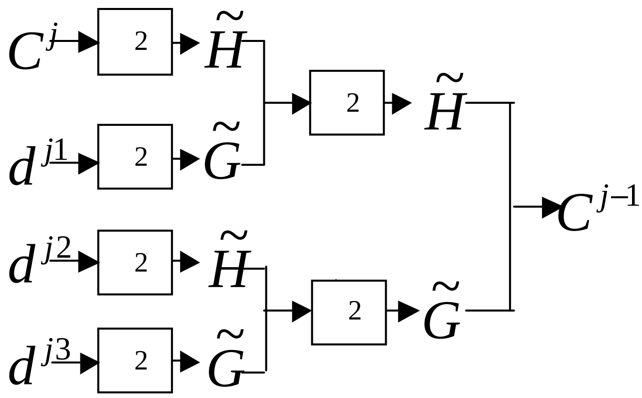

Fig.3 wavelet transform reconstruct algorithm

3.2 Image fusion algorithm

As we know, the image information which was processed by wavelet transform was composed of some coefficients. There will have some coefficients are eminent when image information is similar to the wavelet base function. For example, the coefficients of C^j are more eminent than those in the d^{j1}, d^{j2} and d^{j3} if there are more homogeneous regions in image C^{j-1}, and the coefficients of d^{j1} are more eminent than those in others images if there are more vertical edges in image C^{j-1}. The predominant coefficients illustrate that the information which they describe are very distinct in their images. So we compare the coefficients between SAR image and optical image in same subimage and select the bigger as a group new coefficients to do inverse wavelet transform and get the fusion image. The processing depicted in figure 4.

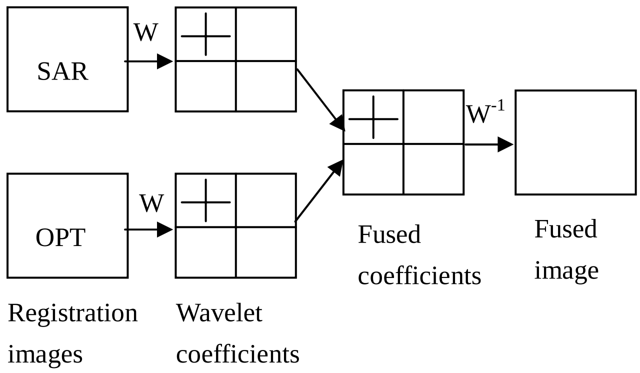

Fig.4 fusion of wavelet transformation of two images

4 Experiment results

We applied our algorithm to somewhere port region in SIR-C/X-SAR images and optical images at the same scene. The resolutions of the data used in experiments are 25m and 5m about SAR image and optical image, respectively. The experimental results are shown in Fig.5-Fig.8, which include linear targets in the port areas. We applied the Dabuenchies wavelet to process 3 layers transformation in SAR image and optical image.

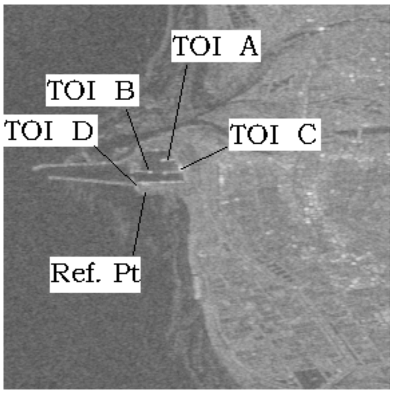

Fig.5 SIR-C X band SAR image

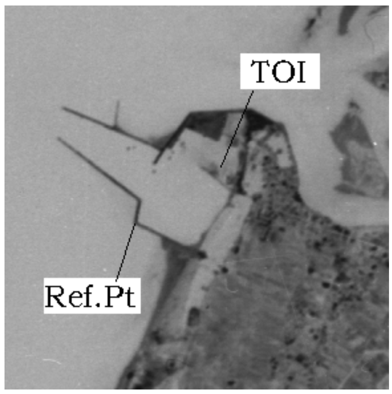

Fig.6 optical image

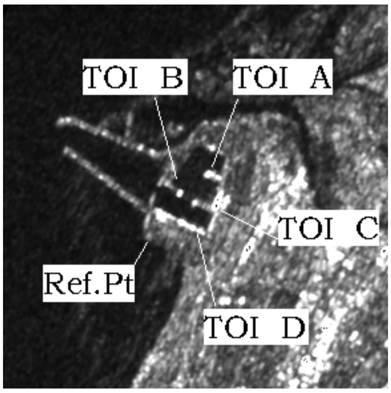

Fig.7 Image after linear polynomial matching based on optical image

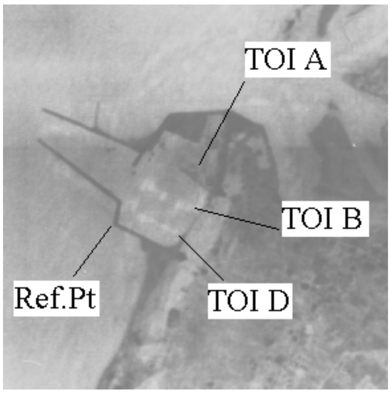

Fig.8 fusion image

Quality assessment of fused images is often carried out by human visual inspection[11], and objective performance assessment is a difficult issue due to the variety of different application requirements and the lack of a clearly defined truth in the ground scene. In the literature [6,12,13] we could find that the authors proposed to use testing of region recognition ,texture-based region segmentation and scene/target identification to assess the fused image. And in this paper, we will give the qualitative evaluations about the experiment results from subjective judgement and partly objective description. We create a coordinate system in the inflection point which is regarded as the original point.and we measure the distance between reference point and left point of the interesting targets. The relatively targets sizes are tested at the current resolution.

Table 1-3 shows the information that we can get from the SIR-C/X SAR image ,optical image and fusion image.

Table 1: information from SAR image

	Description	Distance	Length	Width
RP	Ref. Point	0	0	0
TOI A	Strong lin. tar.	400	225	25
TOI B	Strong lin. tar.	275	275	25
TOI C	Strong lin. tar.	225	250	25
TOI D	Strong lin.tar.	100	575	25

Table 2 : information from the optical image

	Description	Distance	Length	width
RP	Ref.Point	0	0	0
TOI	Dark tar.	320	145	10

Table 3: information from fusion image

	Description	Info. Source	Distan ce	Lengt h	Wid th
RP	Ref. Point	SAR Opti	0	0	0
ToIA	Strong above water	SAR Opti	320	145	10
TOIB	Strong under water	SAR	180	225	15
TOID	Strong under water	SAR	85	240	15

RP: Reference Point
TOI: Targets of Interest
We can get some conclusions from above tables:

1 Because of using the optical image information the resolution was improved from 25m to 5m in SAR image with the result that we could make the precise explication about TOI and decline the permitted error.
2 TOI A in optical image is the same one as in SAR image. And in SAR image TOI B met up with TOI C as one TOI in fusion image. The reason is that there have some other facts caused wane in the connected TOI B for SAR echoes.
3 TOI B/C and TOI D had same characters for SAR echo and were invisible for optical image. The reasons caused this phenomenon were present as follow:
   i) the experiment SAR image and optical image did not capture at the same time and TOI B/C and TOI D did not exist when captured the optical image;
   ii) in the regions there did not vary during captured the SAR image and optical image but there had could or other man made shelters hidden the TOI B/C and TOI D in optical image;
   iii) TOI B/C and TOI D are underwater targets which were invisible for optical image and those characters for SAR echo were very strong.

According to the commonsense and SAR experts judgers we think the reason iii) might be reasonable because there are many underwater guardrails for some use in the harbor generally

5 Conclusions

In this paper we proposed a multisensor data fusion algorithm using WT about SAR image and optical image. Image registration is a fundamental task in image processing and quite a few registration techniques have been developed in various fields. We have adopted a affine transformation technique for image registration. The process is carried out on the obvious feature points extracted from the original images using mutual information. In the fusion, we use the time-frequency property of wavelet translation. For any information there only a few coefficients are predominate when we make wavelet translation algorithm about images, and than we selected the bigger coefficient between two images to do inverse wavelet transform and get the fusion image. Our experimental results have shown that the proposed method can efficiently give more accurate and precise detection information than any one single sensor image

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