Multiscale versus Multiresolution Analysis for Multisensor Image Fusion

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ABSTRACT

In this paper, We propose a multisensor image fusion method based on the multiscale decomposition. In this representation, the redundant wavelet transform is performed on input images to emphasise the dominant details present at each scale. A fusion rule is applied between wavelet coefficients in order to produce a fused image. Two different fusion rules are used in the wavelet domain. A quantitative evaluation shows the superiority of our approach over the existing multiresolution method.

1. INTRODUCTION

The availability of multisensor images has led naturally to development of fusion methods. The fusion can be considered as an integration process of multiple sensor images to produce information that cannot be obtained by viewing the sensor outputs separately. The result is a fused image that contains more suitable information to improve human visual perception.

The fusion of multisensor images can be conducted through many rules. The most simple rule consists of averaging two or several available images to produce a single fused image. This approach is intuitive but not efficient because it creates a blurred fused image. This limitation is due to the fact that it operates only in the spatial domain.

Another more efficient approach to produce a fused image can be considered by using the wavelet transform. In fact, the image description in the wavelet domain allows a better characterization [3]. Many strategies of fusion, defined by a fusion rule, may then be applied between the wavelet coefficients of the multisensor images. And the fused image is thus obtained as a result of a reconstruction from the ensuing wavelet coefficients.

The image representation in the wavelet domain can be achieved by a multiresolution [3] or multiscale [1] decomposition. The multiresolution decomposition allows to create four images (lower resolution, horizontal, vertical and diagonal detail images) at each level with decimation of data. While the multiscale decomposition provides, at each level, two images of the same size as that of the image at the previous level : the coarser scale and detail images.

We consider in this paper the fusion of multisensor images by exploiting the

multiscale representation. We will show that it represents a more efficient alternative method to obtain a better visual perception in the fused image.
Evaluation criteria are defined used to compare the multiscale and multiresolution representations for image fusion. Two different fusion rules are utilised for this purpose.

2. IMAGE FUSION AND WAVELET

2.1. Fusion Concept

The goal of image fusion is to create a new image fusion that is more suitable for the purposes of human visual perception.

The direct combination is not appropriate since it is difficult to define an efficient rule to select the pertinent information from the input image. This difficulty has led many authors to consider representations of the images in domains where an easier selection may be performed. The wavelet transform appears as a powerful tool for this purpose.

In the wavelet domain, the image is represented by a set of coefficients called wavelet coefficients. This representation leads to a spread of the information following scales, allowing a description of the image from a fine to coarse resolution. The fusion becomes then a simple procedure that reduces to define a selection rule to apply between the wavelet coefficients at each level.
Subsequently a fused image is constructed by performing an inverse wavelet transform from the selected coefficients.

2.2. Discrete Wavelet Transform Algorithms

Many works led to the development of discrete wavelet transform algorithms. The most known is the Mallat algorithm which is based on the multiresolution representation and allows the decomposition of the image on an orthogonal wavelet base. This algorithm provides wavelet coefficients with decimation by two at each level and there is no redundancy of information through levels of the decomposition. While the multiscale representation allows to decompose the image on an non orthogonal wavelet base, and corresponds to a redundant representation of the data.

In practice, multiresolution and multiscale decompositions using the wavelet transform are performed by *Mallat* [3] and *à trous* algorithms [1] respectively.

2.3. Redundant Versus Orthogonal Wavelet Transform

In the multisensor image fusion, the use of the orthogonal wavelet transform has shown the limit of this approach since it creates artifacts in the fused image [5]. The use the redundant wavelet transform is intuitively a more suited approach in order to ensure a better fusion. The fact that there is a redundancy of the information following scales allows that a pertinent detail at a given scale to appear at other scales. And if a non pertinent detail as the noise is present at a scale, it does not appear in next scales. This characteristic is exploited in the fusion process of multispectral images.

2.4. Fusion Rules in the Wavelet Domain

The multiresolution decomposition is already used for image fusion. It consists in producing at each level a decision map between wavelet coefficient images [4].

The most simple fusion rule is to take the coefficient which has the maximum absolute amplitude (MAA) from the input images at each location in the wavelet domain.

However, this rule can produce a fused image that contains much noise.

A more efficient rule may be used by considering a window around the central coefficient in the wavelet domain where we count the number of significant coefficients having the maximum absolute amplitude. The selected coefficient in the fused image will be the one that has the maximum number of significant coefficients. This rule allows to eliminate the noise coming from input images. For this reason, this rule is called the maximum absolute amplitude consistency verification criterion (MAACV).

3. RESULTS

3.1. Image Simulation

To evaluate the performances of the fusion, we have simulated test images. The two images to fuse are obtained by applying different blurring to the same original image (Image.1.a). The first image (Image 1.b) is obtained by blurring the left side part of the original image while the second one is produced by blurring the right side part (Image 1.c).
It is expected that the fused image will contain all the features of the original image.

We give below (Image 1.d) the result of image fusion obtained by multiscale representation using the MAACV rule. We can see that original and fused images are very similar.

3.2. Evaluation criteria

As a quantitative evaluation of the fusion performances, three parameters : Difference in means (Δm), Difference in standard deviations (Δs) and RMS error (r) are computed for both multiresolution and multiscale representations.. These results are summarized in table 1 where the MAA is used and in table 2 where MAACV is considered. We can take note, in all cases, that the multiscale representation gives better results.

Decomposition	Δm	Δs	r
Multiresolution	0.244363	0.714179	4.337578
Multiscale	0.129415	-0.346909	2.211626

Table 1. Comparison of multiresolution and multiscale representations with maximum absolute amplitude rule

Decomposition	Δm	Δs	r
Multiresolution	-0.238276	-0.902580	3.406593
Multiscale	-0.082733	0.279266	1.987012

Table 2. Comparison of multiresolution and multiscale representations with consistency verification rule

3.3. Radar and optical image fusion

We give in Image 2 an example of fusion of two images obtained by the multiscale representation. The selected images are Landsat TM5 and ERS1 radar. We see clearly that a better visual perception is obtained in the fused image.

4. CONCLUSION

The main contribution of this paper is to provide a more efficient alternative to the multisensor image fusion by using the multiscale representation. The redundant wavelet transform allows to verify the consistency of dominant features at each scale. The fine details are better enhanced in comparison with the multiresolution representation.
The measured performances indicate that the multiscale representation gives improved results, and thus it can be considered as a new robust tool for the multisensor image fusion.

References :

[1] A. Bijaoui, J.L. Starck, F. Murtagh, « Restauration des images multi-échelles par l'algorithme à trous », *Traitement du Signal*, Vol.11, No.3, 1994

[2] L. J. Chipman, T. M. Orr, « Wavelets and image fusion », *ICIP'95*, pp.248-251

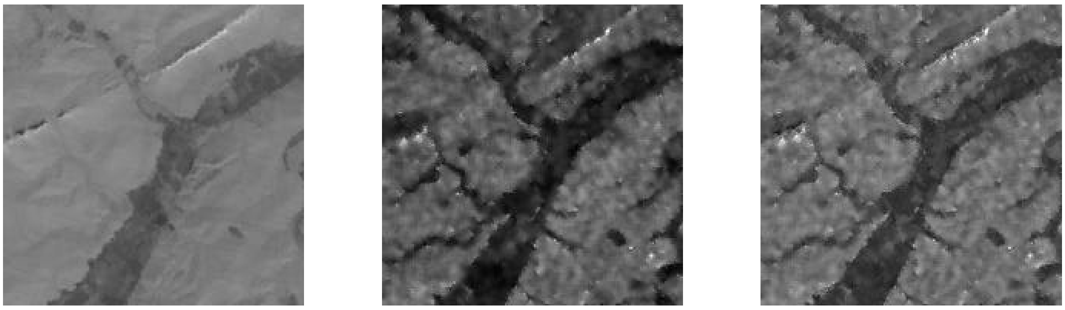
[3] S. G. Mallat, « A theory for multiresolution signal decomposition : The wavelet representation », *IEEE Trans., Pattern Anal. Mach. Intell*, Vol.11, July 1989

[4] H. Li, B. S. Manjunath, S. K. Mitra, « Multisensor image fusion using the wavelet transform », *Graphicals Models & Image Processing*, Vol.57, No.3, May 1995

[5] D. A. Yocky, « Artifacts in wavelet image merging », *Optical Engineering*, Vol.35, No.7, July 1996

(a) (b) (c) (d)

Image 1.(a) Original image (b) Blurred image in left hand side (c) Blurred image in right hand side (d) Fused image of two blurred images by the multiscale analysis



(a) (b) (c).

Image 2. Image fusion with multiscale representation.
(a) Landsat TM5 (b) ERS1 radar image (c) Fused image