

A COMPREHENSIVE QUALITY EVALUATION METHOD OF INFORMATION FUSION FROM HIGH-RESOLUTION AIRBORNE SAR AND SPOT5 IMAGES

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ABSTRACT:

The image fusion of high-resolution Airborne SAR and SPOT5 can bring us high spatial resolution spectrum and texture information. When analysing and evaluating the fusion image, we usually take the information entropy as a simple evaluation standard, which maybe loss some other information we need. Actually, as many researchers have pointed out, it should be done comprehensively, combining objective with subjective evaluation standards. That is to say, the optimum method is to carry on objective quantitative evaluation on the basis of subjective qualitative visual evaluation. According to the image characteristics of airborne SAR and SPOT5, this paper discussed several indexes such as entropy, mean value, standard variance and so on. And, combining with subjective analysis result, a comprehensive quality evaluation of the fusion images with structural similarity can be obtained. At the last, a test has testified it and corresponding analysis result has been presented.

1. INTRODUCTION

The fusion technique of remote sensing images aims to improve the capability of application and detection the ground objects. And usually, the fusion image data is a group of new space information and combined images. So that, for the different sensor data, it can combine the advantages of different remote sensing data resources, compensating the deficiency of some data resource, to decrease the uncertainty, improve the accuracy of remote sensing image classification and the capability of dynamic monitoring (Gemma, 2004).

During the recent years, the quick development of Synthetic Aperture Radar (SAR) got more and more attention in the world. SAR has the advantage of full-time, full-weather, penetrability for cloud and rain, even some vegetation with the change of radar wavelength, high-resolution (e.g. airborne SAR with 1-meter resolution), and more texture information. But in practical applications, there exists some type of the ground objects which are difficult to be recognized by human eye's vision, as a result of SAR side-imaging mode, the influence of noise and shadow, vision levels and so on. For example, because of the shelter and shadow, it will be difficult for the trees and buildings with height to produce mapping quickly (Guo, 2000; Ulaby, 1987).

At the same time, SPOT5 image data has the characteristics of high resolution, capability of side observation to produce stereo images, and obtaining image of the same area in short time, which are gained more and more attention from the consumers in remote sensing field. In the research fields such as land use and managing, forest cover monitoring, soil eroding, and city planning, it has shown important effect. So, the fusion image can take full advantage of SAR and SPOT5 data, to obtain the multi-level information of ground objects, improve the objects characteristic and the classification accuracy of the ground cover (Pohl, 1998; Tupin, 2003; Solberg, 1997).

2. THE DECISION OF OBJECTIVE AND SUBJECTIVE EVALUATION INDEXES FOR THE FUSION IMAGES OF SAR AND SPOT5

2.1 Use of Fusion Image and Evaluation Objective

In this paper, the fusion image of high-resolution airborne SAR and multi-spectral SPOT5 data is mainly applied in terrain mapping, so that, there will be three objectives for the image fusion as following that are:

- To improve image resolution: Generally speaking, the processing of image fusion between the lower-resolution multi-spectral remote sensing data and the higher-resolution airborne SAR data can obviously improve the image resolution, simultaneously preserving enough texture information.
- To enhance the information quantity: For an effective image characteristic extracting, it is necessary to enhance the information quantity of ground types from SAR data, to obtain the facility of vision recognizing.
- To improve the definition: During the image processing, we need improve the image quality enhances the image detail information, and texture characteristic, under the condition of preserving the original image information as soon as possible. For SAR image, it is difficult to preserve the edge information and energy utilizing the common ways of image enhancing unless the image fusion.

2.2 Choice Method of Evaluation Index

Usually, for the image quality evaluation of fusion images, the evaluation index items applied in fusion image evaluation are included the subjective and objective evaluation indexes, decided by the objectives and use of the fusion image from high-resolution airborne SAR and SPOT5 data. The subjective evaluation indexes are often the base criterion for the image interpreting researchers, with simple and direct characteristic. Meanwhile, the common objective index items involve such as information entropy, mean gradient, correlation coefficient, and mean value, standard variance and so on. However, in the processing of evaluating the fusion images, there exist many subjective factors influencing the eventual evaluation result, and the common objective evaluation methods may not make the best of the characteristic of human visual system (Wang, 2003).

In this paper, the choice of evaluation index will mainly depend on the relationship between the original and fusion

image, with a comprehensive considering of the subjective and objective evaluation methods.

2.3 Structural Similarity

During observing images, what the human eyes practically extracted are not the error between image pixels but the image structure information. And, human visual system can self-adaptively extract the structure information in image background. At present, many researchers have pointed out that the structure distortion is the most important factor in image quality assessment. This viewpoint has given a new direction for now image quality assessment research, and already achieved much research production (Wang, 2002; Xydaes, 2000; Di, 2006). This paper adopted the formulation as following to describe the structure similarity between the original and fusion images.

Suppose A, B represents respectively the original and fusion image, then the structure similarity (SS) between them will be defined as:

$$SS_{AB} = L_{AB} \cdot C_{AB} \cdot S_{AB} = \frac{2\mu_A\mu_B}{\mu_A^2 + \mu_B^2} \cdot \frac{2\sigma_A\sigma_B}{\sigma_A^2 + \sigma_B^2} \cdot \frac{\sigma_{AB}}{\sigma_A\sigma_B} \quad (1)$$

Where, there are:

$$\sigma_A^2 = \frac{1}{MN-1} \sum_{m=1}^M \sum_{n=1}^N (A(m,n) - \bar{A})^2 \quad (2)$$

$$\sigma_{AB} = \frac{1}{MN-1} \sum_{m=1}^M \sum_{n=1}^N (A(m,n) - \bar{A})(B(m,n) - \bar{B})$$

In the above formula, μ_A and μ_B are respectively the mean value of the image window; σ_A^2 and σ_B^2 are respectively the variance of the image window; σ_{AB} is the covariance of A and B image window data; L_{AB} , C_{AB} , S_{AB} is respectively the compare items of lightness, contrast, and structure between the two images, with values between 0 and 1.

The structure similarity value is between [-1.1], and with a value close to 1, the fusion image will have a higher quality. It combines the image structure information and human visual system characteristic to evaluate the fusion image quality, with a better effect than the other subjective or objective index separately.

3. THE COMPREHENSIVE EVALUATION MODEL FOR THE FUSION IMAGE

In the processing of fusion image quality evaluation, we must consider the relationship among the original image A and B and the fusion image F, to construct the corresponding evaluation index, because the fusion result image derives of the two original remote sensing data. In this paper, we adopt the construction function E (A, B, F) to evaluate the fusion image quality synthetically (Hu, 2004), which is as following:

$$E(A, B, F) = \lambda_A SS_{AF} + \lambda_B SS_{BF} \quad (3)$$

$$\lambda_A = \frac{s_A(\omega)}{s_A(\omega) + s_B(\omega)}$$

$$\lambda_B = 1 - \lambda_A$$

Where, λ_A and λ_B are respectively the SS weight value of the original and fusion images; $S_A(\omega)$ and $S_B(\omega)$ are the variance value of the original images A and B. The above formula can synthetically evaluate the structure similarity between the fusion and original images. But, in view of the characteristics of high-resolution airborne SAR and SPOT5 images, the human visual system will have different visual levels for different ground object types, especially for the trees, building, water, road, land cover and mountain shadow and so on. Considering this, we put forward a kind of comprehensive fusion quality (CFQ) evaluation model, according to the interpreting characteristic of the different ground object types, with a formulation as:

$$CFQ = \prod_{k=1}^K \theta_k E_k(A, B, F) = \prod_{k=1}^K [\lambda_A SS_{AF}(k) + \lambda_B SS_{BF}(k)] \quad (4)$$

$$k = 1, 2, 3, \dots, K$$

Where, K represents the sum number of types discussed in the fusion result image; θ_k is the corresponding weight value for each ground object type.

4. TEST AND RESULT ANALYSIS

In this paper, we take high-resolution airborne SAR, with a resolution of 1 meter, and 10-meter resolution multi-spectral SPOT5 images as the test dataset. And, the latter may combined band 4, 2 and 1 into a pseudo-colour image. The fusion image of airborne SAR and SPOT5 data has just shown in Figure 1.



Figure 1 the fusion result image from airborne SAR and SPOT5

During the data processing, we chose 5 types of ground objects which were often applied in many practical fields, involving buildings, trees, water, road, and land use. From each type, we take 3 samples in the original and fusion result images, utilizing ERDAS software function to obtain the statistical mean value and variance values for each sample window. So, we can discuss the different fusion effect for each type of ground objects, and get the final fusion quality evaluation using the CFQ model described as the above. And, the SS and test result for each type has been seen in Table 1 as following:

type		SS	E	CFQ
Building	SAR	0.9389		0.804
	SPOT5	0.926	0.9328	
	SAR	0.7338		
trees	SPOT5	0.826	0.7777	
Land use	SAR	0.8689	0.896	

	SPOT5	0.9258	
	SAR	0.8508	
Road	SPOT5	0.9141	0.881
	SAR	0.7608	
Water	SPOT5	0.7863	0.7729
	SAR		

Table 1 the SS and test result for each ground object type

As shown in the Table 1, the fusion image of airborne SAR and multi-spectral SPOT5 has a better-recognized capability for the types of trees, land use, and road, with an obvious improvement in the fusion image than the original images. On the contrary, for the types of water and buildings, there is no better enhancement effect than the original images. And meanwhile, the CFQ value is close to 1, implying that the fusion image has got a good effect synthetically, adapt to recognize many types of ground objects for human visual system.

5. CONCLUSIONS

In this paper, a comprehensive fusion image quality evaluation model has been proposed to mainly discuss the interpret effect for many types of ground objects in fusion result image. For the original images, high-resolution airborne SAR and SPOT5 data, some types of ground objects are easily to be recognized in the fusion image, such as trees, land use and road according to the test result, and some other types can only have a weak function for human visual system. That is to say, different types of ground objects have different visual behaviour for human eyes, and this will direct us to choose the right fusion methods and evaluation model against the practical interpret objective. As the test result shown, the CFQ model can provide a reference evaluation index in the processing of fusion image quality evaluation.

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