

# A Comprehensive Evaluation Model for Remote Sensing Fused Image

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**Abstract.** This paper presents a novel evaluation model for remote sensing fused images. Meanwhile, take IHS-RPCA and NSCT-SF-PCNN as an example, the simulation experiments are analyzed and measured by the proposed comprehensive evaluation metric model. In addition, we brief introduce the choice for the weight  $\omega$ . Through this study we conclude that the proposed evaluation model is valid for the measure for remote sensing fused images.

## Introduction

Image fusion is an image processing method that can be described as combining information from images of different sources or modalities into a composite image.

The fusion of multispectral (MS) and panchromatic (PAN) images, with complementary spectral and spatial characteristics, is becoming a promising technique to obtain images with high spatial and spectral resolution simultaneously. Due to the advances in satellite technology, a great amount of image data has been available and widely used in different remote sensing applications, such as feature detection, change monitoring, urban analysis, and land cover classification etc. Thus, image data fusion has become a valuable tool in remote sensing to integrate the best characteristics of each sensor data involved in the processing.

At present, there are many fusion rules, such as discrete cosine transform (DCT) [1], pyramid transforms [2], multiscale geometric transforms [3], and wavelets transform (WT) [4] etc. However, how to measure the quality of fusion rules is still an important issue.

Image quality assessment (IQA) aims to use computational models to measure the image quality consistently with subjective evaluations. Since the subjective IQA methods are easily influenced by many factors including viewing distance, display device, lighting condition, subjects' vision ability, and subjects' mood etc. Therefore, it is necessary to design mathematical models that are capable of predicting the quality evaluation of an average human observer.

In this paper, we will establish an evaluation model of full reference (FR) with weight, and take remote sensing fused images as examples. The evaluation model can be mathematically described as the following:

$$\mathcal{C}_{FAB} = \omega_{FA} \mathcal{E}_{FA} + \omega_{FB} \mathcal{E}_{FB} \quad (1)$$

where  $\mathcal{C}_{FAB}$  denotes the comprehensive evaluation metric of fused image  $F$  and reference images  $A$  and  $B$ ;  $\mathcal{E}_{FX}$  denotes the relative evaluation metric of fused image  $F$  and reference image  $X$  ( $X = A, B$ );  $\omega_{FX}$  denotes the weight of  $\mathcal{E}_{FX}$  ( $X = A, B$ ) in comprehensive evaluation and satisfies  $\omega_{FA} + \omega_{FB} = 1$ . In the following, let  $A = \text{MS}$ ,  $B = \text{PAN}$ ,  $\omega = \omega_{FA}$ .

## Simulation Experiments

In this section, we will perform simulation experiments using NSCT-SF-PCNN fusion [5] and IHS Combined Robust PCA transformation fusion [6], respectively. The results for simulation experiments are separately shown in the Fig. 1(a) and Fig. 1(b).

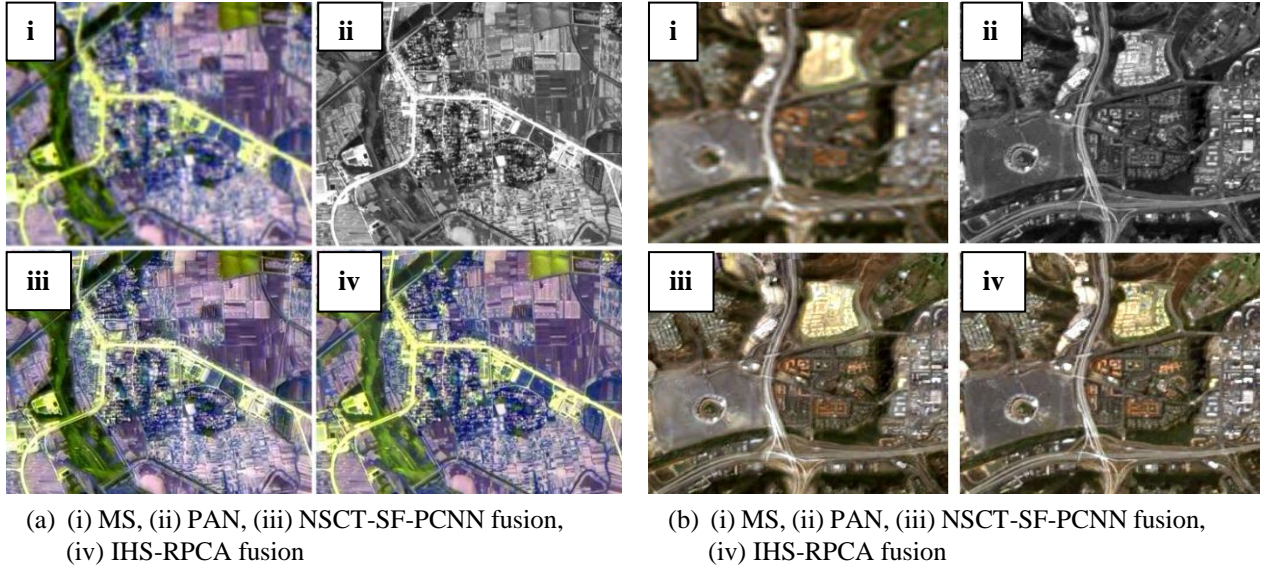


Fig. 1: Simulation Experiments

### Image Evaluation and Data Analysis

Visual comparison indicates that IHS combined RPCA transform fusion show better visual interpretability compared to the NSCT-SF-PCNN fusion techniques (see Fig. 1(a) and Fig. 1(b)).

Statistics	Technique	Bands for $\mathcal{E}_{FA}$			Bands for $\mathcal{E}_{FB}$		
		1	2	3	1	2	3
CC	NSCT+PCNN	0.9375	0.9381	0.9375	0.9267	0.9302	0.9243
	IHS+RPCA	0.9203	0.9197	0.9203	0.9315	0.9280	0.9338
SSIM	NSCT+PCNN	0.9450	0.9440	0.9500	0.9228	0.9254	0.9190
	IHS+RPCA	0.9118	0.9129	0.9056	0.9352	0.9327	0.9387
MI	NSCT+PCNN	0.9604	0.9622	0.9531	0.9051	0.9215	0.9092
	IHS+RPCA	0.8916	0.8890	0.9017	0.9504	0.9364	0.9472
RMSE	NSCT+PCNN	0.9068	0.9072	0.9172	0.9670	0.9186	0.9483
	IHS+RPCA	0.9491	0.9488	0.9403	0.8816	0.9391	0.9078
Warp	NSCT+PCNN	0.9003	0.9007	0.9119	0.9667	0.9130	0.9484
	IHS+RPCA	0.9541	0.9538	0.9449	0.8820	0.9440	0.9076

Table 1: Evaluation Metric  $\mathcal{E}_{FA}$  and  $\mathcal{E}_{FB}$  for Fig. 1(a)

To objective evaluate the ability of enhancing spatial details and preserving spectral information, we will utilize the comprehensive evaluation metric defined by equation (1).

At first, we give some statistical parameters, such as correlation coefficient (CC), structural similarity index method (SSIM)[7], mutual information (MI) [8], root mean squared error (RMSE), and spectral distortion (warp) (see Table 1 and Table 2). For the metrics CC, SSIM and MI, a larger value means a better performance, whereas a smaller value implies better performance for RMSE and warp. Then, let  $\omega \in (0, 1)$ , using Table 1 and equation (1), we can obtain the following Fig. 2(a). Meanwhile, similar the Fig. 2(a), applying Table 2 and equation (1), we also have the Fig. 2(b).

From Fig. 2(a) and Fig. 2(b), it is not difficult to found that the comprehensive evaluation metric  $\mathcal{E}_{FAB}$  of IHS-RPCA are monotonically decreasing as  $\omega$  increasing in statistical parameters CC, SSIM

and MI, but that are monotonically increasing in statistical parameters RMSE and Warp. Whereas the comprehensive evaluation metric  $\mathcal{E}_{FAB}$  of NSCT-SF-PCNN are just different from IHS-RPCA, that are monotonically increasing in CC, SSIM and MI, and monotonically decreasing in RMSE and Warp.

Statistics	Technique	Bands for $\mathcal{E}_{FA}$			Bands for $\mathcal{E}_{FB}$		
		1	2	3	1	2	3
CC	NSCT+PCNN	0.9033	0.9020	0.8918	0.8554	0.8542	0.8563
	IHS+RPCA	0.8619	0.8581	0.8521	0.8795	0.8792	0.8801
SSIM	NSCT+PCNN	0.9211	0.9174	0.9014	0.8551	0.8541	0.8502
	IHS+RPCA	0.8602	0.8549	0.8364	0.8804	0.8795	0.8869
MI	NSCT+PCNN	0.9332	0.9284	0.9085	0.8046	0.7884	0.8092
	IHS+RPCA	0.8405	0.8389	0.8286	0.8981	0.8909	0.9045
RMSE	NSCT+PCNN	0.7990	0.8035	0.8165	0.9104	0.9430	0.9411
	IHS+RPCA	0.8829	0.8911	0.9100	0.8451	0.8237	0.8055
Warp	NSCT+PCNN	0.7931	0.7988	0.8115	0.8880	0.9219	0.9457
	IHS+RPCA	0.8831	0.8923	0.9147	0.8619	0.8424	0.8038

Table 2: Evaluation Metric  $\mathcal{E}_{FA}$  and  $\mathcal{E}_{FB}$  for Fig. 1(b)

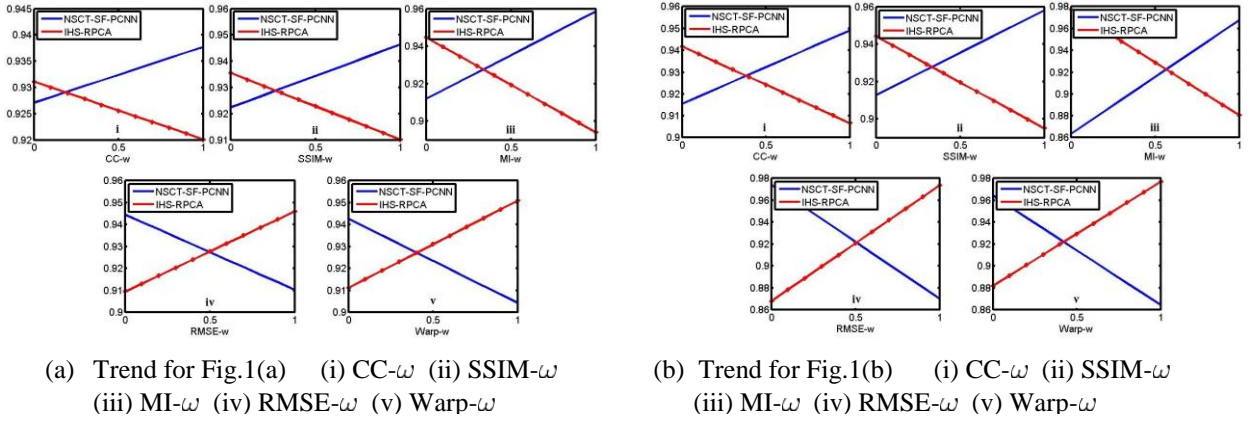


Fig. 2: Trend of Comprehensive Indexes for NSCT-SF-PCNN & IHS-PRCA

$\mathcal{E}_{FAB}$	Technique	CC	SSIM	MI	RMSE	Warp
Fig. 1(a)	NSCT+PCNN	0.9303	0.9296	0.9259	0.9344	0.9312
	IHS+RPCA	0.9278	0.9279	0.9295	0.9205	0.9231
Fig. 1(b)	NSCT+PCNN	0.9190	0.9208	0.8951	0.9225	0.9142
	IHS+RPCA	0.9177	0.9145	0.9285	0.9003	0.9100

Table 3: Average Value of Comprehensive Evaluation Metric  $\mathcal{E}_{FAB}$  for Fig. 1

The change of weight  $\omega$  evidence the variation of proportion for relative evaluation metric  $\mathcal{E}_{FA}$  in the comprehensive evaluation metric  $\mathcal{E}_{FAB}$ . When  $\omega = 0$  or  $\omega = 1$ , the comprehensive evaluation metric  $\mathcal{E}_{FAB}$  only include  $\mathcal{E}_{FB}$  or  $\mathcal{E}_{FA}$ , it means the main component is the high spatial resolution panchromatic image PAN in the comprehensive evaluation metric  $\mathcal{E}_{FAB}$ , or the high spectral

resolution image MS. To Fig. 2(a) and Fig. 2(b), it can see the horizontal coordinates for intersection points are located between 0.15 and 0.55. Taking into account the fact that the fusion process is performed at a coarser scale, that is the low resolution MS image is brought to the geometric size of the high resolution PAN image. Thus, in order to overcome this problem and objectively evaluate image,  $\omega$  will take the suitable values ( $0 < \omega < 0.5$ ) to measure the fusion algorithms. And it is easy to verify that the fusion algorithm IHS-RPCA is better than the NSCT-SF-PCNN in  $\omega \in (0.15, 0.45)$  (see Table 3). Meanwhile, it also show that IHS-RPCA algorithm can enhance spatial details, whereas NSCT-SF-PCNN can preserve more spectral information.

## Summary

This paper presents a novel evaluation model for remote sensing fused images. Meanwhile, take IHS-RPCA and NSCT-SF-PCNN as an example, the simulation experiments are analyzed and measured by the proposed comprehensive evaluation metric model. In addition, we brief introduce the choice for the weight  $\omega$ . Through this study we conclude that the proposed evaluation model is valid for the measure for remote sensing fused images.

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