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A Toolbox for Teaching Image Fusion in Matlab

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Abstract

In the study, an interface toolbox for image fusion (IFT) is developed and implemented of using the Matlab programming language. MATLAB developed by MathWorks is suitable for rapid application development and also its scope is scripts and functions can be run as m-files in the open source program Octave. In program, the interface toolbox is created to integrate from different types of satellite images to a single enhanced image. This image fusion toolbox is useful at the undergraduate students to understand the results of the image enhancements technique and the integration of remotely sensed images.
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1. Introduction

Digital image processing is a discipline which can be applied in many areas such as astronomy, genetics, remote sensing, video communication, biomedical, transportation system. Image processing is the most common course at the undergraduate and graduate level in Computer and Information Technology (CIT) programs at universities in Turkey. The purpose of this course is to provide students for the problem-solving skills as an in-depth introduction to the fundamentals of computer vision and computer graphics.

Nowadays, there are many image processing libraries for different development environments, e.g. OpenCV, AforgeNet, EmguCV, Matlab image processing toolbox. Especially, computer simulations using both the mathematical modelling and the software toolbox development in Matlab is an easy and helpful way to teach the theoretical and practical aspects of the courses such as image processing and machine learning etc. But at least, it

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requires an intermediate level knowledge of the C programming language to use Matlab functions to create a toolbox. Matlab is a software package providing a programming language and toolboxes for technical computation of algorithms, visualization and analysis of data in science, education and engineering applications. Using the MATLAB programming language, students can implement their projects more rapidly than with traditional programming languages, such as C, C++, and Fortran (Varga & Varga 2010; Tong et al. 2011) .

Undergraduate students of CIT programs have programming capability and software implementations of processing algorithms, but most of them may have little knowledge about solving and understanding complex equations in the digital image processing topics including image fusion, filtering, segmentation and classification etc. The main objective of this paper is to present, as a case study, the crucial role of using simulation toolbox that developed to imagine how easy to learn the solution of the complex mathematical models adapted to the real-world activity. In this paper, an interface toolbox in Matlab, which can be used for fusion of MS and Pan satellite images, developed to improve students' intuitive feeling with theories and applications to meet the students' practical requirements in the course (Fan et al. 2009) The toolbox is designed to be used without any advanced knowledge in programming and image processing theory. All the operations (fusing and quality analysis) can be performed with aid of the program interface without writing code. And it is very simple to display original inputs (MS and Pan images), fused image and qualitative results after the processing.

The remainder of this paper is organized as follows. In section 2, a brief introduction of the IHS based image fusion is given. Section 3 describes the quality metrics for the quality analysis of fused images. The program interface and sample implementation is given in section 4, followed by the discussion and conclusion in section 5

2. Image Fusion

Image fusion, is a technique used to integrate spatial information of high resolution panchromatic (Pan) image and spectral information of low resolution multispectral image to produce high resolution MS image that has similar to original data sets. A variety of image fusion techniques and software tools has been developed to implement many specific applications in remote sensing. Among the most commonly used methods for satellite image fusion are IHS, Brovey transform, PCA and Wavelet based fusion methods (Zhang 2004; Pohl & van Genderen 1998). All of fusion methods are not available in commonly used commercial software packages such as ENVI, ERDAS and PCI. However, it is also possible to develop toolbox in Matlab for use and practice in undergraduate image processing courses.

IHS fusion technique is a popular image fusion method with fast computing capability and ability of quickly merging massive volume of data (Tu et al. 2004). IHS technique converts RGB (Red, Green, Blue) values to intensity, hue and saturation values, is one of the most commonly used image fusion techniques. In the IHS space, hue and saturation reflect mostly spectral information. Fusion of Pan and MS remote sensing images is applied to ensure the spectral information and add the detail information of high spatial resolution. IHS employs a 3x3 matrix to transform RGB space to IHS space and various IHS transformations which have different values of matrix are used in many published studies.

One of the IHS techniques used in this study is cylinder color model transform. Cylinder color model based IHS transformation assumes that IHS coordinate system can be represented as a cylinder. The cylinder transformation model has the following equation:

$$\begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} \\ -1/\sqrt{6} & -1/\sqrt{6} & 2/\sqrt{6} \\ -1/\sqrt{2} & 1/\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} \Longrightarrow \begin{bmatrix} Pan \\ v_1 \\ v_2 \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} 1/\sqrt{3} & -1/\sqrt{6} & -1/\sqrt{2} \\ 1/\sqrt{3} & -1/\sqrt{6} & 1/\sqrt{2} \\ 1/\sqrt{3} & 2/\sqrt{6} & 0 \end{bmatrix} \begin{bmatrix} Pan \\ v_1 \\ v_2 \end{bmatrix} \tag{3}$$

After applying first equation above, the intensity band (I) is replaced by high-resolution Pan image and then fused image (R'G'B') can be easily obtained by inverse transformation.

3. Quality Analysis

The spatial prominence of images provided by image fusion methods can be considered visually and statictically. In visual consideration, color similarity, image distortions and seperation of objets are taken into account (Cetin & Musaoglu 2009). However, this is not the only way to measure the quality of method because visual assessments are subjective. To make them objective, statistical methods are used as well as visual methods. In implementation, ERGAS, SAM, SSIM, and correlation coefficients are used to statistically analyze the introduced method. The quality metrics are briefly explained below.

3.1. SSIM(StructuralSimilarity Index Method)

SSIM is a full-reference quality metric used to assess similarity between two images, SSIM is calculated as in equation 15 – the results are in the range between -1 and +1. The more the result is closer to +1, the more the similarity is high(Chen 2011). SSIM is calculated as in equation 4 – the resuls are in the range between -1 and +1.The more the result is closer to +1, the more the similarity is high.

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x{}^2 + \mu_y{}^2 + c_1)(\sigma_x{}^2 + \sigma_y{}^2 + c_2)} \tag{4}$$

3.2. ERGAS (ErreurRelativeGlobaleAdimensionnelle de Synthese)

ERGAS is a quality measurement used in enhancement of low frequency and multispectral images, proposed by Lucien Wald in 2000 (Wald 2000). This method is based on root mean square error (RMSE) and is used to assess the quality of images from synthesis of higher spatial resolution images.

$$RMSE(B_k) = \frac{1}{PS}\sqrt{\sum_{k=1}^{N}(B_k - B_k^*)^2} \tag{5}$$

$$M = \frac{1}{N}\sum_{k=1}^{N} M_k \tag{6}$$

$$ERGAS = 100\frac{h}{l}\sqrt{\frac{1}{N}\sum_{k=1}^{N} RMSE(B_k)^2 \Big/ (M_k)^2} \quad (7)$$

3.3. SAM (SpectralAngleMapper)

SAM calculates spectral similarities between images by looking at the angle between two vectors (original and fused images). It takes images as vectors and finds the angle α between them by equation 17 (Wang et al. 2004). The mentioned t_i and r_i stand for i th band of test and reference images respectively, and b is the number of bands.

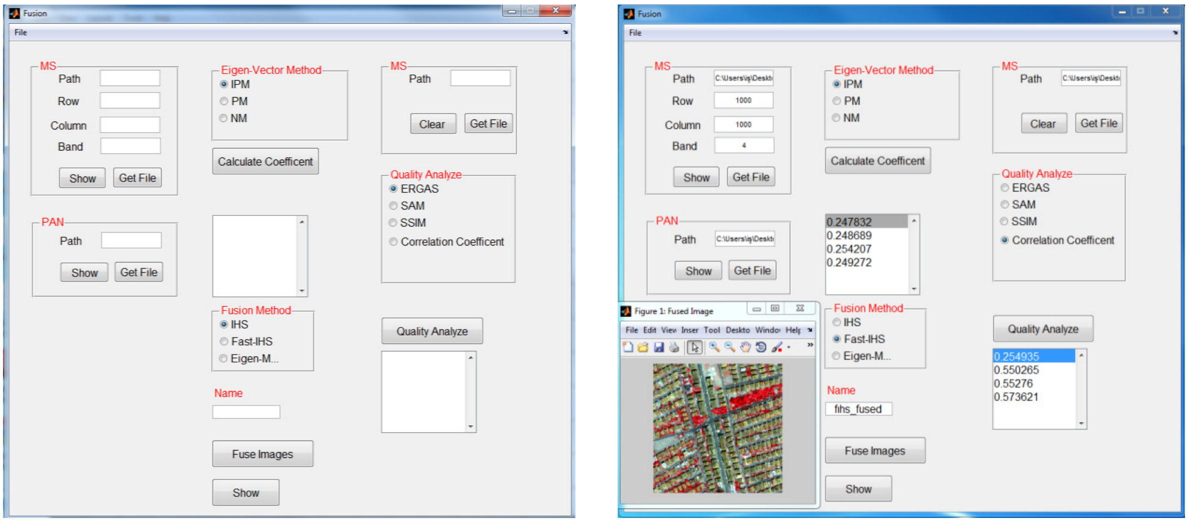
In equation 11 t_i and r_i represent ith band of test and referance image respectively. And b is the number of the band i

$$\alpha = cos^{-1}\left(\frac{\sum_{i=1}^{b} t_i r_i}{\left(\sum_{i=1}^{b} t_i^{2}\right)^{1/2}\left(\sum_{i=1}^{b} r_i^{2}\right)^{1/2}}\right) \quad (8)$$

4. Image Fusion Toolbox (IFT) and Implementation

The application is designed as shown in figure 1. In the first step, MS and Pan images are given to the program by the application interface. Users can display the true colors of images at the runtime. MS and Pan images must have same dimensions, otherwise the program gives an error message and doesn't allow moving to the next step. In the second step, one of the image fusion methods should be selected. In next step, the weight coefficients are calculated and displayed in textbox according to the selected method. Finally, a name of the output file should be given than the process is completed and fused image is displayed and saved.

At the same time, there is a analyses section for statistical quality control of the fused image in the program. The original MS and fused images are compared by the quality metric which is selected. Finally the qualitative results are shown in textbox.



a) IFT GUI b) IFT application

Fig. 1. The Toolbox Interface

Quickbird satellite image, acquired on 30 August 2009 in Kayseri province, the interior Anatolian region in Turkey, are chosen in order to implement the designed image fusion toolbox. The size of the test images, belong to urban small area, are 1000x1000 pixels for the panchromatic image and 250x250 pixels for the multispectral images as shown in figure 2.

(a) MS urban (b) PAN urban

(c) Enhanced image with IHS fusion method

Fig. 2. Original and fused images.

Visual results of the fused image are displayed in fig 1c and the results of the quality metrics are given in Table 1.

Table 1. Quality analysis results

	ERGAS	SSIM	SAM
PM-IHS	5.0209	0.7644	2.5084
IHS	11.7205	0.5402	3.4415
GIHS	5.04231	0.7628	2.5229
GIHSF	3.6869	0.7821	1.6805

5. Conclusion

In the study, an interface toolbox for image fusion is developed and implemented of using the Matlab programming language to support the image processing education at the undergraduate and graduate level in Computer and Information Technology (CIT) programs at universities in Turkey. It is designed specifically for intermediate students to improve in their skills and abilities in the remote sensing. After a brief introduction to the use of toolbox, the students can easily use it to learn the basis of remote sensing data and image fusion techniques.

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