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Development of Multi-focus Image Fusion Technique using Discrete Wavelet Transform (DWT) for Digital Images

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Abstract

Image fusion is the process which combines information of multiple images from the same scene. The resultant fused image is a new image that have the most desirable information and characteristics of each input image. One of the main application of image fusion is merging the gray-level high-resolution panchromatic image and the colored low-resolution multispectral image. It has been found that the standard fusion methods perform well spatially but usually introduce spectral distortion. To overcome this problem, numerous multi-scale transform based fusion schemes have been proposed. In this paper, we focus on the fusion methods based on the Discrete Wavelet Transform (DWT), the most popular tool for image processing. Due to the numerous multi-scale transform, different fusion rules have been proposed for different purpose and applications.

Keywords: Image Fusion, DWT, Wavelet Transform, IHS, PCA.

Introduction

Image fusion is a synergistic tool that serves to combine multiple-source imagery. It aims to integrate all complementary data from several images into a single image in order to enhance the apparent information in the images. Fusion of images is often acquired from different instruments (or multi-sensors), or the same sensor with different measuring contexts. The recent advances in the field make it possible to implement across wide areas such as medical imaging, microscopic imaging, remote sensing, computer vision and robotics. Fusion technique includes different methodologies, starting from pixel level to feature level and symbol level. The pixel level implies algorithmic combination of vector of measurement from each image. Feature level requires post-processing of classification and segmentation of input images and fusion is based on those extracted features. This enables detection of useful feature with higher confidence. Symbol level allows information to be effectively combined at the highest level of abstraction. In all the three methodologies, the knowledge of underlying physical process is required. In order to approach non-phenomenological way, that tends to ignore the physical process and attempt to fuse data regarding their statistical nature, the scientific literature presents various statistical techniques, like maximum amplitude signal, averaging, weighted average, Bayesian approach and Dempster–Shafer methods. In the field of non-destructive evaluation (NDE), the main purpose is to provide information about the presence, the location and the size of potential defects on or into the inspected components. Different inspection techniques and sensors are used for analyzing components in order to acquire complementary information about defects. Furthermore, for a proper exploitation of the data measured by the different sensors, or by the same sensor in different measuring contexts, it is mandatory to develop effective data fusion techniques able to take advantage of such multi-sensor characteristics. The definition of multi-sensor fusion is broad and the fusion can take place at pixel, feature and symbol level. However, when these methods are applied, some undesired effects of contrast reduction can appear. Many fusion methods have been exploited in recent years. Some methods are based on component substitution, such as Intensity Hue Saturation (IHS) transform that distorts the spectral feature, and high pass filter (HPF) method and principle component analysis (PCA), which loose the physical features of source images. Among different methods, the wavelet transform (WT) is efficiently applied to multi-sensor image fusion because of its properties such as multi-resolution analysis and accurate reconstruction. The

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WT contains unique information at different resolutions that other traditional method cannot. But the selection of a particular wavelet filter and the choosing of different decomposition schemes affect the overall performance of image fusion. In the field of NDE, fusion of images demands for the elimination of noise while retaining the information about defects. Hence, the selection of an appropriate wavelet filter and an optimum decomposition level are important for getting better results. Research on the subject of strategic combination of information while eliminating noise signals has been motivated by a desire to obtain more appropriate parameter for the selection of the wavelet filters and the level of decomposition.

Image fusion process

Fig.1 shows the principal processes in a generic image fusion processing chain for the case when the output is a single fused image I. The principal processes in the chain are:

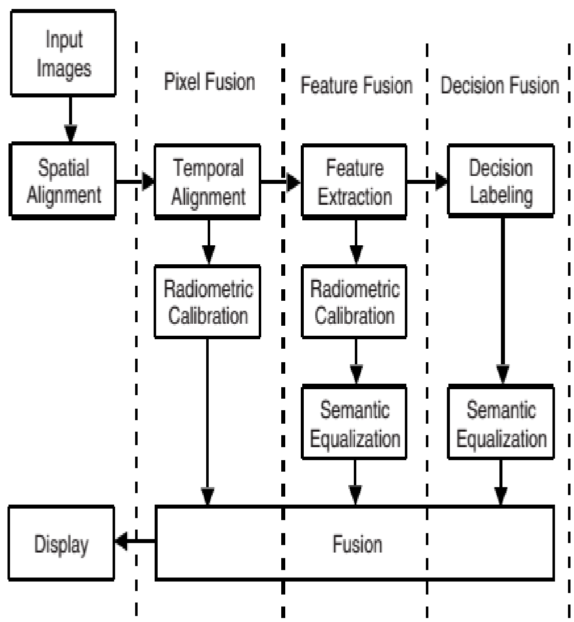

Fig.1 Shows the generic image fusion processing chain It consists of four principal blocks: (1).Multiple Input Images (2). Common Representational Format (3). Fusion (4). Display.

Multiple Input Images

The external environment is captured by one or more image sensors or cameras. Each camera generates one or more input images.

Common Representational Format

The input images are transformed so they "speak a common language". This involves several processing including: spatial, temporal, semantic and radiometric alignment, feature extraction and decision labelling.

Fusion

After conversion into a common representational format the spatially, temporally, semantically and radio-metrically aligned images, feature maps or decision maps are fused together in the fusion block. The output is a fused image I, feature map F or decision map D.

Display

The fused image, feature map or decision map is processed for display.

Common representational

The principal function in the common representational format block are:

Spatial Alignment

The input images are spatially aligned into the same geometric base. Without a common geometric base any information derived from a given input image cannot be associated with other spatial information. The accurate spatial alignment of the input images is therefore a necessary condition for image fusion. After spatial alignment the input images are re-sampled and if necessary the gray-levels of the input images are interpolated.

Temporal Alignment

The spatially aligned input images are temporally aligned to a common time. This step is only required if the input images are changing or evolving in time. In this case the accurate temporal alignment of the input images is a necessary condition for image fusion.

Feature Extraction

Characteristic features are extracted from the spatially and temporally aligned input images. The output is one or more feature maps for each input image.

Decision Labelling

Pixels in each spatially and temporally aligned input image or feature map are labelled according to a given criteria. The output is a set of decision maps.

Semantic Equivalence

In order for the input images, feature maps or decision maps to be fused together they must refer to the same object or phenomena. The process of causally linking the different inputs to a common

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object or phenomena is known as semantic equivalence.

Radiometric Calibration

The spatially, temporally and semantically aligned input images and feature maps are converted to a common measurement scale. This process is known as radiometric calibration.

Format Fusion using Discrete Wavelet Transform (DWT)

The fusion of two images within the wavelet domain is formally considered the Discrete Wavelet Transform (DWT) of two registered input images and is combined with the definite fusion rule. Then the inverse DWT (IDWT) is computed and the fused image is reconstructed [13]. The process is shown in Fig.2 and is defined as:

$$I(x.y) = W^{-1}[\varphi\{W(I_1(x,y)), W(I_2(x,y))\}]$$

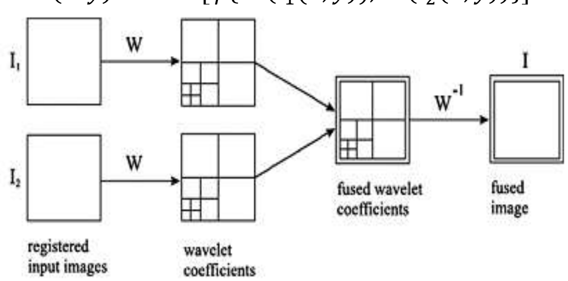

Fig.2 Fusion of Two Images using DWT.

Where I_1, I_2 are the two images to fuse, φ is the fusion rule, and W and W^{-1} are the DWT and IDWT, respectively. Obviously, the procedure can be extended to multiple images, fusing the result coming from two images with the third image, and so on. For each one of the considered applications, the main user-related activity is based on the selection of proper wavelet filter and level of decomposition. In fact, case by case, these two parameters should be selected according to the framework, the available measurements and the aims and definite information that desired to be obtained. In general, the main aim is to emphasize the informative content of measures neglecting the noise impact.

Flow Chart

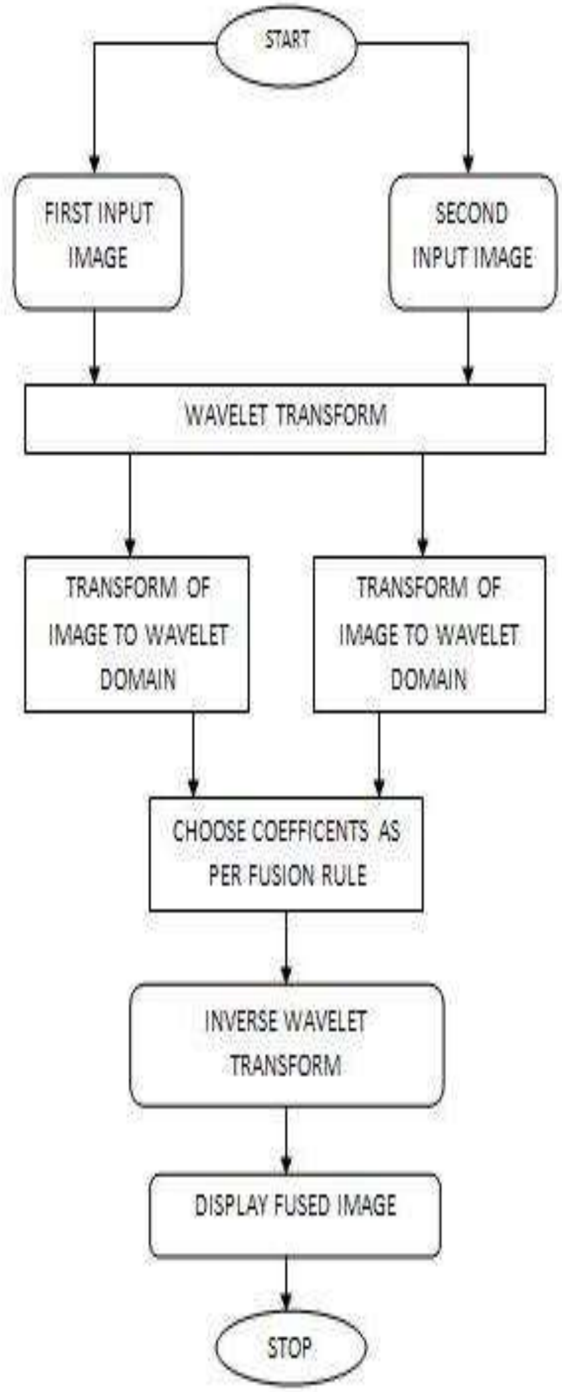

Fig.3 Flow Chart of Fusion Process using Wavelets.

Experimental Results and Discussion

The fusion is conducted on coloured images having size 640x480 each. Registered input images are transformed into wavelet coefficient by using wavelet transformation (DWT) then these input

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images are as wavelet coefficients combined or fused together with definite fusion rule. Then the inverse DWT (IDWT) is computed and the fused image is reconstructed. For taking the wavelet and inverse wavelet transform of the images, available MATLAB commands are used. We take first input image as shown in Fig. 4, the left portion of this image is blurred and then second input image as shown in Fig. 5, right portion of this image is blurred. After wavelet fusion a fused output image is taken out as shown in Fig. 6, this output image is more informative as compared to both of the input images. Red, Blue and Green contents of the fused output image is shown in Fig. 7.

Fig.4 First Input Image

Fig.5 Second Input Image

Fig.6 Fused Output Image

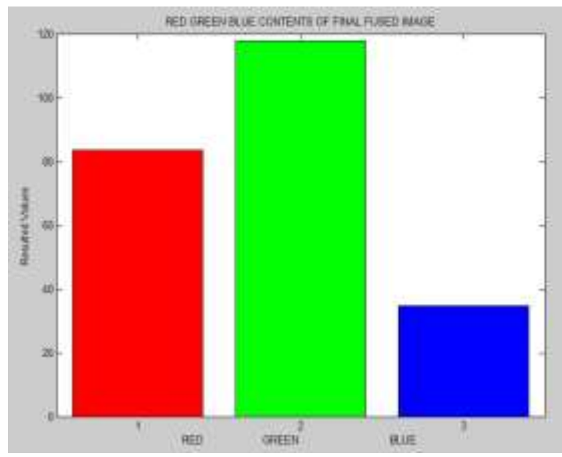

Fig.7 Output Image in Red, Blue and Green Contents

Conclusion

After obtaining the results using this technique we have concluded that the Discrete Wavelet Transforms is the very good technique for the image fusion provide a high quality spectral content. Wavelet Transform provides very good results both quantitatively & qualitatively for area level fusion due to its improved directionality and preserves geometric structures more faithfully. Hence using these fusion methods, one can enhance the image with high geometric resolution and better visual quality.

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