Image Fusion Technique - A Review

Chetan Dhanraj Zope, Prof. Arun E. Kachare

***Abstract*— Image fusion is one of important image processing technologies. The main aim of image fusion is to create new images that are more suitable for the purposes of human/machine perception and for further image-processing tasks such as segmentation, object detection or target recognition in applications like medical imaging and remote sensing. In this paper, we have presented the basic principles of image fusion at the level of pixel, feature and decision. We have reviewed the design techniques of laplacian pyramid image fusion and wavelet based image fusion. Literature survey of these image fusion techniques is presented. The working of these image fusion techniques is then presented. The system has many functions: image denoising, image enhancement, image registration, image segmentation, image fusion and fusion evaluation.**

***Index Terms*— Image fusion, laplacian pyramid, wavelet.**

I. INTRODUCTION

In image fusion, several images from different image sensors are fused in order to obtain a new image that contains more information and has more positive image description to the same scene. So far image fusion has been widely used not only in some military fields, such as object detecting and tracing, context awareness and so on, but also in many civil fields which include navigation of airport, security control, intelligent traffic, geographical information system, medical imaging, and human being visual aids and so forth [1]. Multi-sensor images often have different geometric representations, which have to be transformed to a common representation for fusion. This representation should retain the best resolution of sensor. A prerequisite for successful in image fusion is the alignment of multi-sensor images. Multi-sensor data often presents complementary information, so image fusion provides an effective method to enable comparison and analysis of data. However, image fusion does not necessarily provide multisensory sources, there are interesting applications for both single-sensor and multi-sensor image fusion.

Single-Sensor Image Fusion System: A single sensor image fusion system is shown in Figure1. The sensor shown could be a visible-band sensor such as a digital camera. This sensor captures the real world as a sequence of images. The sequence is then fused in one single image and used either by a human operator or by a system to do some task [4].

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Chetan Dhanraj Zope, Department of E&TC Amrutvahini College of Engineering, Sangamner, Maharashtra, India
Prof. Arun E. Kachare, Department of E&TC, Amrutvahini College of Engineering, Sangamner, Maharashtra, India

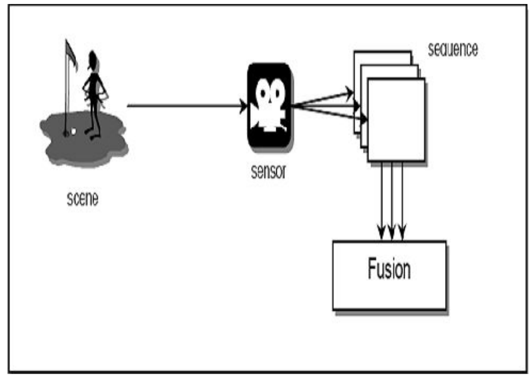

Fig. 1: Single sensor image fusion system

This kind of systems has some limitations due to the capability of the imaging sensor that is being used. The conditions under which the system can operate, the dynamic range, resolution, etc. are all limited by the capability of the sensor. For example, a visible-band sensor such as the digital camera is appropriate for a brightly environment such as daylight scenes but is not suitable for poorly situations found during night, or under conditions such as in fog or rain.

Multi-Sensor Image Fusion System: A multi-sensor image fusion system overcomes the limitations of a single sensor fusion system by combining the images from these sensors to form a composite image. Figure 2 shows working of a multi-sensor image fusion system. In this case, an infrared camera is being used the digital camera and their individual images are fused to obtain a fused image. This approach overcomes the problems referred to single sensor image fusion system, while the digital camera is appropriate for daylight scenes; the infrared camera is suitable in poorly illuminated ones [4].

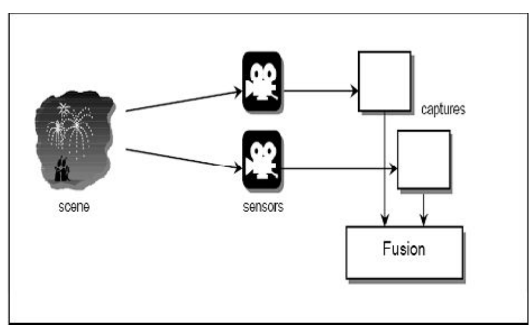

Fig. 2: Multi -Sensor Image Fusion System

Advantages of Multi-sensor Image Fusion:

[1]Extended range of operation – multiple sensors that operate under different operating conditions can be deployed to extend the effective range of operation.

[2] Extended spatial and temporal coverage – joint information from sensors that differ in spatial resolution can increase the spatial coverage.

[3] Reduced uncertainty – joint information from multiple sensors can reduce the uncertainty associated with the sensing or decision process.

[4] Increased reliability – the fusion of multiple measurements can reduce noise and therefore improve the reliability of the measured quantity.

[5] Robust system performance – redundancy in multiple measurements can help in systems robustness. In case one or more sensors fail or the performance of a particular sensor deteriorates, the system can depend on the other sensors.

[6] Compact representation of information – fusion leads to compact representations. For example, in remote sensing, instead of storing imagery from several spectral bands, it is comparatively more efficient to store the fused information.

II. Literature Survey

Dong-Chen He [15], presented a new and original method of fusion, capable of combining a high resolution image with allow resolution image with or without any spectral relationship existing between these two images; preserving the spectral aspect of the low resolution image while integrating the spatial information of the high resolution image.

Firooz Sadjadi [16], described a method for evaluating the performance of image fusion algorithms. He defined a set of measures of effectiveness for comparative performance analysis and then used them on the output of a number of using algorithms that have been applied to a set of real passive infrared (IR) and visible band imagery. Further he concluded that the comparative merit of each fusion method is very much dependent on the measures of effectiveness being used. However, many of the fusion methods produced results that had lower measures of effectiveness than their input imagery.

Tian Hui [17], described image fusion in detail and introduced the three basic levels which are pixel level, feature level and decision level fusion, and then compared with their properties and all other aspects. Then they described the evaluation criteria of image fusion results from subjective evaluation and objective evaluation two aspects. According to the quantitative evaluation of the image fusion results and quality, this text uses and defines multiple evaluation parameters such as fusion image entropy, mutual information MI, the average gradient, standard deviation, cross-entropy, unite entropy, bias, relative bias, mean square error, root mean square error and peak SNR, and establishes the corresponding evaluation criteria. Further they concluded that in the subjective evaluation of image fusion, visual characteristics, psychological status, cultural background, environmental conditions all will have a significant impact on the evaluation results, so an objective evaluation criteria was established. They also established quantitative evaluation methods and criteria of the multi-sensor image fusion performance and quality are objective, reasonable and effective. The establishment of the evaluation methods and criteria has important meaning for the further in-depth expansion of the multi-sensor image fusion research.

Chun Hua Wang [18], introduced the concept of the image fusion technology and its division level. Image fusion by the different levels of information abstraction can be divided into three levels: Pixel-level fusion, Feature-level fusion and Decision-level fusion. It reviews the image fusion at pixel level technology and probes into the form of image fusion method of evaluation criteria. At last it gives the development direction of image fusion.

Zhihui Wang [19], introduced the basic principles of image fusion at the level of pixel, feature, and decision. They described the design rules and steps of Graphical User Interface (GUI). Image fusion system based on GUI is then designed and implemented. They further introduced the framework of the overall design of the system and its usage method is explained The system has many functions: image denoising, image enhancement, image registration, image segmentation, image fusion and fusion evaluation. Especially can the system implement image fusion based on wavelet or multi-wavelets or PCNN or Match Measure of Pulse Number (MMPN). In order to show that the system is intuitive and easy to use, they apply it to visible image and IR image.

Wencheng Wang [1], presented a simple and efficient algorithm for multi-focus image fusion, which used a multi-resolution signal decomposition scheme called Laplacian pyramid method. They introduced the principle of Laplacian pyramid transform and based on it the fusion strategy is described in detail. The method mainly composed of three steps. Firstly, the Laplacian pyramids of each source image are deconstructed separately and then each level of new Laplacian pyramid is fused by adopting different fusion rules. To the top level, it adopts the maximum region information rule; and to the rest levels, it adopts the maximum region energy rule. Finally, he fused image is obtained by inverse Laplacian pyramid transform. Two sets of images are applied to verify the fusion approach proposed and compared it with other fusion approaches. By analyzing the experimental results, it showed that this method has good performance, and the quality of the fused image is better than the results of other methods.

M.Pradeep [4], presented an approach to implement image fusion algorithm i.e. Laplacian Pyramid. In this technique he implemented a pattern selective approach to image fusion. The basic idea is to perform pyramid decomposition on each source image and finally reconstruct the fused image by performing an inverse pyramid transform. It offers benefits like resolution, S/N ratio and pixel size. The aim of image fusion, apart from reducing the amount of data, is to create new images that are more suitable for the purposes of human/machine perception, and for further image-processing tasks such as segmentation, object detection or target recognition in applications such as remote sensing and medical imaging Based on this technique finally it reconstructs the fused image from the fused pyramid.

III. Fusion techniques

1. Laplacian Pyramid Method : It represents the edge of the image detail at every levels, so by comparing the corresponding Laplace-level pyramid of two images, it is possible to obtain the fused image which merge their respective outstanding detail, and makes the integration of the image retaining the amount of information as rich as possible. The source image is decomposed into a series of resolution spaces, and how to choose integration factor and fusion rule will directly affect the final quality of fused image [2,3]. Generally speaking, there are two fusion methods: the pixel-based and region-based. Though pixel-based method is simple and has less computation, the performance is poor. Because the local characters of an image are not dependent each other, there are more relationships among one pixel with its neighbours. So the fusion operators based on the region method can be designed. The principle is as shown in Fig.3

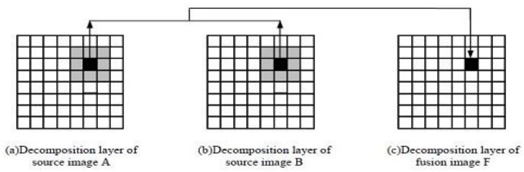

Fig. 3: Fusion Strategy Based Region

The important issue for image fusion is to determine how to combine the sensor images. In last few years, several image fusion techniques have been proposed [1]. The important fusion schemes perform the fusion right on the source images. One of the simplest of these image fusion methods just takes the pixel- by-pixel gray level average of the source images. This simplistic approach has disadvantage such as reducing the contrast. With the introduction of pyramid transform, it was found that better results were obtained if the fusion was performed in the transform domain. The pyramid transform appears to be very useful for this purpose. The first task is to perform a multi resolution decomposition on each source image, then integrate all these decompositions to form a composite representation and then finally reconstruct the fused image by performing an inverse multi-resolution transform. Several types of pyramid decomposition or multi-scale transform are used or developed for image fusion such as Laplacian Pyramid as shown in figure4. With the development of wavelet theory, the multi-scale wavelet decomposition has begun to take the place of pyramid decomposition for image fusion.

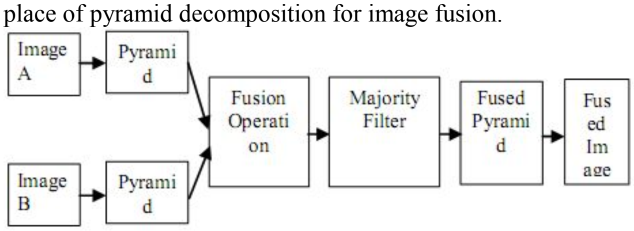

Fig. 4: Laplacian Pyramid Fusion Method

2. Wavelet based Image Fusion: It is a non-redundant decomposition algorithm, the amount of information will not be increased in the process of the wavelet decomposition and thus the wavelet transform can be used to obtain the images consistent with human visual frequency characteristics. The image fusion algorithm based on wavelet transform and clarity can be described as follows.

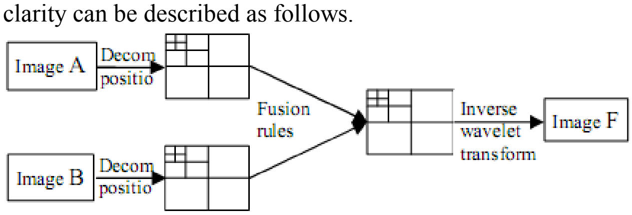

Fig. 5: Wavelet based Image Fusion

First, the various source images will be decomposed into a series of sub-images with different resolutions; and then the fusion rule based on clarity is used to fuse the high-frequency sub-image; the appropriate weighting coefficients are applied for the same low frequency sub-images; finally the obtained sub images with different resolutions will be fused in terms of the wavelet reconstruct algorithm.

IV. Fused Image Quality Assessments

Standard Deviation (STD) - It is an important index to weigh the information capability of images and it reflects the discrete level of gray-scale image's mean value, The Standard deviation is defined as

$$STD = \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j)-\hat{\mu})^2 / MN}$$

The greater the standard error, the more dispersed the distribution of gray-scale image, the better the quality of fused image. That is to say, it contains more information.

Spatial Frequency Component (SF) – It measures the overall activity level in an image. For an M x N image F, with the gray value at pixel position (m, n) denoted by F(m,n), its spatial frequency is defined using Equation,

$$SF = \sqrt{RF^2 + CF^2}$$

where RF and CF are the row frequency and column frequency respectively.

$$RF = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}(F(m,n)-F(m,n-1))^2}$$

$$CF = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}(F(m,n)-F(m-1,n))^2}$$

The SF can be used to reflect the clarity of an image. Without regard to noise, the large value of SF demonstrates that the image is sharp.

Performance Measurement - The $Q^{AB/F}$ framework [8] associates important visual information with gradient information and assesses fusion by evaluating the success of gradient information transfer from the inputs to the fused image. Fusion algorithms that transfer more input gradient information into the fused image more accurately are said to perform better. Specifically, assuming two input images A and B and a resulting fused image F, a Sobel edge operator is applied to yield the strength g and orientation α([0,π]) information for each input and fused image pixel. Using these parameters, relative strength and orientation "change" factors G and A, between each input and the fused image, are derived.

$$G_{n,m}^{AF} = \begin{cases} \dfrac{g_{n,m}^{F}}{g_{n,m}^{A}}, & if \quad g_{n,m}^{A} > g_{n,m}^{F} \\ \dfrac{g_{n,m}^{A}}{g_{n,m}^{F}}, & otherwise \end{cases}$$

$$A_{n,m}^{AF} = 2\pi^{-1}\left\| \alpha_{n,m}^{A} - \alpha_{n,m}^{F} \right| - \pi/2 \right|$$

These factors are the basis of the edge information preservation measure Q^{AF} obtained by sigmoidal mapping of strength and orientation change factors. This quantity models the perceptual loss of input information in the fused image and constants Γ, κ_g, σ_g, κ_a, σ_a determine the exact shape of the sigmoid mappings:

$$Q_{n,m}^{AF} = \Gamma(1+e^{\kappa_g(G_{n,m}^{AF}-\sigma_g)})^{-1}(1+e^{\kappa_\alpha(A_{n,m}^{AF}-\sigma_\alpha)})^{-1}$$

Total fusion performance $Q^{AB/F}$ is evaluated as aweighted sum of edge information preservation values for both input images Q^{AF} and Q^{BF} where the weights factors w^A and w^B represent perceptual importance of each input image pixel. The range is $0 = Q^{AB/F} = 1$, where 0 means complete loss of input information has occurred and 1 indicates "ideal fusion" with no loss of input information. In their simplest form, the perceptual weights w^A and w^B take the values of the corresponding gradient strength parameters g_A and g_B.

$$Q^{AB/F} = \frac{\sum_{\forall n,m} Q_{n,m}^{AF} w_{n,m}^{A} + Q_{n,m}^{AF} w_{n,m}^{B}}{\sum_{\forall n,m} w_{n,m}^{A} + w_{n,m}^{B}}$$

CONCLUSION

This paper first introduces importance of image fusion and then presents fusion techniques; laplacian pyramid image fusion and wavelet based image fusion. Fused image quality assessments show various parameters using which we can obtain experimental results of fused image using laplacian pyramid image fusion and wavelet based image fusion method. It helps in comparative analysis of both fusion techniques.

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