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REVIEW ON IMAGE FUSION

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ABSTRACT

Image fusion is a process of blending the complementary as well as the common features of a set of images, to generate a resultant image with superior information content in terms of subjective as well as objective analysis point of view. The objective of this research work is to develop some novel image fusion algorithms and their applications in various fields such as crack detection, multi spectra sensor image fusion, medical image fusion and edge detection of multi-focus images etc. Image Fusion is such a technique of producing a superior quality image from a set of available images. It is the process of combining relevant information from two or more images into a single image wherein the resulting image will be more informative and complete than any of the input images. A lot of research is being done in this field encompassing areas of Computer Vision, Automatic object detection, Image processing, parallel and distributed processing, Robotics and remote sensing.

Keywords: CT(Computerized Tomography), MRI(Magnetic Resonance Imaging), PET(Positron Emission Tomography), HIS(Intensity Hue Saturation), RGB(Red Green Blue)

I. INTRODUCTION

Image fusion is the process by which two or more images are combined into a single image retaining the important features from each of the original images. The fusion of images is often required for images acquired from different instrument modalities or capture techniques of the same scene or objects [1]. Several approaches to image fusion can be distinguished, depending on whether the images are fused. The purpose of image fusion is to combine information from several different source images to one image, which becomes reliable and much easier to be comprehended by people [2][3]. Image fusion can be broadly defined as the process of combing multiple input images or some of their features into a single image without the introduction of distortion or loss of information. The objective of image fusion is to combine complementary as well as redundant information from multiple images to create a fused image output. Therefore, the new image generated should contain a more accurate description of the scene than any of the individual source image and is more suitable for human visual and machine perception or further image processing and analysis task. The fusion process should be shift and

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rotational invariant; it means that the fusion result should not depend on the location and orientation of an object the input image. The main principles of image fusion are the redundancy, the complementary, the time-limit and low cost

A. Basic Levels of Image Fusion

Image fusion can be divided into three levels: pixel-level fusion, feature-level fusion and decision-level.

- **Pixel Level Fusion**

Image fusion at pixel-level means fusion at the lowest processing level referring to the merging of the measured physical parameters and its application is very wide. At this level it has the details on the information which other levels do not have. [4][5] The data level fusion is also called pixel level fusion, which means the direct process of data taken from sensors. It is the foundation of high level image fusion and one important direction of present image fusion research. The merit of this fusion method is keeping the living original data as much as possible, which provides the details those other level fusion methods, cannot supply

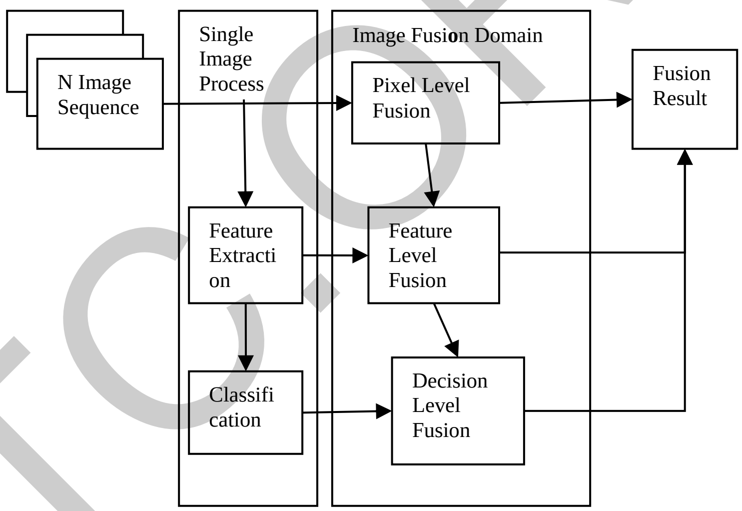

Fig. 1: Image fusion block scheme of different abstraction levels

- **Feature Level Fusion**

Feature-level fusion is done in the course of image feature extraction. It's the medium level fusion and prepared for decision-level fusion. In the process of feature-level fusion, features of every image are extracted. The same kind of features of different images is organically synthesized. The typical features are edge, shape, profile, angle, texture, similar lighting area and similar depth of focus area. While fusing features, the forms and contents of main features are correlative with the applied purpose and situation of image fusion [6]. The feature-level algorithms typically segment the image into contiguous regions and fuse the regions together using their properties. The features used may be calculated separately from each image or they may be obtained by the simultaneous processing of all the images. Piella proposed several activity level measures including the absolute

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value, the median, or the contrast to neighbor's measures. Finally, she proposed a region-based scheme using a local correlation measurement to perform the fusion of each region [7].

- **Decision-level fusion**

Decision-level fusion is the highest-level fusion. All decision and control are decided according to the results of decision-level fusion. Decision level fusion falls under a broader area known as distributed detection systems and is the process of selecting one hypothesis from multiple M hypotheses given the decisions of multiple N sensors in the presence of noise and interference. [8] In biometrics, decision level fusion creates a single decision from typically two hypotheses, imposter or genuine user, from multiple biometric sensor decisions, which may or may not be identical sensors.

II. Medical Imaging Modalities

The introduction of advanced imaging techniques has improved significantly the quality of medical care available to patients. Noninvasive imaging modalities allow a physician to make increasingly accurate diagnoses and render precise and measured modes of treatment. There are various types of medical imaging modalities used today which are as follows:

- **X-ray Imaging**

X-ray technology is the oldest and most commonly used form of medical imaging. X-rays use ionizing radiation to produce images of a person's internal structure by sending X-ray beams through the body, which are absorbed in different amounts depending on the density of the material. Radiation Therapy is a type of device which utilizes either x-rays, gamma rays, electron beams or protons to treat cancer.

- **Computed Tomography (CT)**

Computed Tomography (CT), also commonly referred to as a CAT scan, is a medical imaging method that combines multiple X-ray projections taken from different angles to produce detailed cross-sectional images of areas inside the body. CT images allow doctors to get very precise, 3-D views of certain parts of the body, such as soft tissues, the pelvis, blood vessels, the lungs, the brain, the heart, abdomen and bones. CT is also often the preferred method of diagnosing many cancers, such as liver, lung and pancreatic cancers.

- **Magnetic Resonance Imaging (MRI)**

Magnetic Resonance Imaging (MRI) is a medical imaging technology that uses radio waves and a magnetic field to create detailed images of organs and tissues. MRI has proven to be highly effective in diagnosing a number of conditions by showing the difference between normal and diseased soft tissues of the body.

- **Positron Emission Tomography (PET)**

Positron Emission Tomography (PET) is a nuclear imaging technique that provides physicians with information

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about how tissues and organs are functioning. PET, often used in combination with CT imaging, uses a scanner and a small amount of radiopharmaceuticals which is injected into a patient's vein to assist in making detailed, computerized pictures of areas inside the body.

- **Ultrasound Imaging Diagnostic**

Ultrasound, also known as medical sonography or ultrasonography, uses high frequency sound waves to create images of the inside of the body. The ultrasound machine sends sound waves into the body and is able to convert the returning sound echoes into a picture. Ultrasound technology can also produce audible sounds of blood flow, allowing medical professionals to use both sounds and visuals to assess a patient's health.

III. Conventional Methods of Image Fusion

- **Spatial Domain Methods**

The term spatial domain refers to the image plane itself and approaches in this category are based on direct manipulation of pixels in an image [12][9]. Spatial domain processes can be denoted by the expression as given by equation

$$g(x, y) = T[f(x,y)]$$

where f (x, y) is the input image, g (x, y) is the processed image and T is an operator on f, defined over some neighborhood of (x, y). One of the principle approaches in this formulation is based on the use of so-called masks (also referred to as kernels, templates, windows or filters) [10]. A mask is a small 2-D array in which the values of the mask coefficients determine the nature of the process, such as image sharpening.

The various spatial domain techniques are illustrated below:

- **Average Method**

The simplest way of image fusion is to take the average of the two images pixel by pixel. Averaging works well when the images to be fused are from same type of sensor and contains additive noise [9].

- **Brovey Transform**

Brovey transform (BT), also known as color normalized fusion, is based on the chromaticity transform and the concept of intensity modulation. It is a simple method to merge data from different sensors, which can preserve the relative spectral contributions of each pixel but replace its overall brightness with the high spatial resolution image. As applied to three MS bands, each of the three spectral components (as RGB components) is multiplied by the ratio of a high-resolution co-registered image to the intensity component I of the MS data.

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- **Intensity Hue Saturation (IHS)**

It is most popular fusion methods used in remote sensing. The fusion is based on the RGB-IHS conversion model, whose various mathematical representations have been developed. No matter which conversion model is chosen, the principle of the IHS transformation to merge images attributes to the fact that the IHS color space is catered to cognitive system of human beings and that the transformation owns the ability to separate the spectral information of an RGB composition in its two components H and S, while isolating most of the spatial information in the I component [11]. In this method three MS bands R, G and B of low resolution Image are first transformed into the IHS color coordinates, and then the histogram - matched high spatial resolution image substitutes the intensity image which describes the total color brightness and exhibits as the dominant component a strong similarity to the image with higher spatial resolution. Finally, an inverse transformation from IHS space back to the original RGB space yields the fused RGB image, with spatial details of the high resolution image incorporated into it. The intensity I define the total colour brightness and exhibits as the dominant component. After resolution using the high resolution data, the merge result is converted back into the RGB After applying an IHS transformation on the low spatial resolution images, we replace the Intensity component by the high spatial resolution image. The fused images are obtained by applying a reverse IHS transformation on the new set of components [12].

- **Principle Component analysis (PCA)**

This technique, also known as the Karhunen-Loeve transform, is extensively used in image encoding, image data compression, image enhancement and image fusion for various mapping and information extraction. The PCA method is similar to the IHS method, with the main advantage that an arbitrary number of bands can be used [13]. The processing program of data fusion by method is as follow:

First, the multi-spectral image is transformed with PCA transform and the eigen values and corresponding eigenvectors of correlation matrix between images in the multi-spectral image's individual hands are worked out to obtain each matrix's principle components. Second, the image is matched by the first principle component using histogram method. Finally, the first principle component of the multi-spectral image is replaced with the matched image and with other principle components, is transformed with inverse PCA transform to form the fused image [5].

After applying a PCA transformation on the low spatial resolution images, we replace the first component by the high spatial resolution image. The fused images are obtained by applying an inverse PCA transformation on the new set of components.

- **Artificial Neural Network (ANN)**

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Inspired by the fusion of different sensor signals in biological systems, many researchers have employed artificial neural networks in the process of pixel-level image fusion. The most popular example for the fusion of different imaging sensors in biological systems is described by Newman and Hart line in the 80s: Rattlesnakes (and the general family of pit vipers) possess so called pit organs which are sensitive to thermal radiation through a dense network of nerve fibers. The output of these pit organs is fed to the optical spectrum, where it is combined with the nerve signals obtained from the eyes. Newman and Hart line distinguished six different types of bimodal neurons merging the two signals based on a sophisticated combination of suppression and enhancement. The performance of ANN depends on the sample images and this is not a characteristics.

IV. Transform Domain Method

Transform domain processing techniques are based on modifying the Fourier transform of image [15].

- **Pyramid Method**

Image pyramids have been initially developed for multiresolution image analysis and as a model for the binocular fusion in human vision. A generic image pyramid is a sequence of images where each image is constructed by low pass filtering and sub sampling from its predecessor. Due to sampling, the image size is halved in both spatial directions at each level of the decomposition process, thus it leads to a multiresolution signal representation. The difference between the input image and the filtered image is so much necessary to allow an exact reconstruction from the pyramidal representation. The image pyramid approach thus leads to a signal representation with two pyramids: The smoothing pyramid containing the averaged pixel values, and the difference pyramid containing the pixel differences which is edges. So we can say that the difference pyramid can be viewed as a multiresolution edge representation of the input image. The basic idea is to construct the pyramid transform of the fused image from the pyramid transforms of the source images, and then the fused image is obtained by taking inverse pyramid transform.

- **Wavelet Transform**

More recently with the development of wavelet theory, people began to apply wavelet decomposition to take the place of pyramid decomposition. It retains most of the advantages for image fusion as compare to other fusion methods. The wavelet transform was applied to image processing successfully, which was first discovered and developed by S. Mallat [17]. Wavelet Transform - The most common form of transform image fusion is wavelet transform fusion. In common with all transform domain fusion techniques the transformed images are combined in the transform domain using a defined fusion rule then transformed back to the spatial domain to give the resulting fused image. Wavelet transform fusion is more formally defined by considering the

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wavelet transforms ω of the two registered input images I1(x,y) and I2(x ,y) together with the fusion rule φ. Then, the inverse wavelet transform ω-1 is computed, and the fused image I (x ,y) is reconstructed .

$$I(x,y) = \omega^{-1}(\phi(\omega(I_1(x,y)), \omega(I_2(x,y))))$$

- **Multiwavelet transform**

Multi-wavelets is an expansion of traditional wavelet and has more advantages. It is most important that a multiwavelets system can simultaneously have these characteristics that are preserving length (orthogonality), good performance at the boundaries because of linear-phase symmetry, and a high order of approximation also named vanishing moments. Thus, multi-wavelets transform offers the possibility of superior performance for image fusion, compared with traditional scalar wavelets [4]. Multiwavelet is an extension from scalar wavelet. It not only maintains the good time-domain and frequency domain localization properties which scalar wavelet possess, but also overcomes the shortcomings of the scalar wavelet.

- **Curvelet Transform**

The curvelet transform has evolved as a tool for the representation of curved shapes in graphical applications. Then, it was extended to the fields of edge detection, image denoising and image fusion [1]. When the curvelet transform (CT) is introduced to image fusion, the fused image will take more characteristics of original images and more information for fusion is maintained [16]. The aim of curvelet transform is to generate an image of better quality in terms of reduced noise than the original image. Conventional methods have very erratic decision making capabilities when compared with curvelet method. Curvelet Transform is a new multi-scale representation most suitable for objects with curves. Curvelet Transformation is an enhancement technique to reduce image noise and to increase the contrast of structures of interest in image. Compared to other techniques, this method can manage the vagueness and ambiguity in many image reconstruction applications efficiently [16].

V. CONCLUSION

Although selection of fusion algorithm is problem dependent but spatial domain provides high spatial resolution. But spatial domain have image blurring problem. The Wavelet transforms is the very good technique for the image fusion. It provide a high quality spectral content.

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