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Satellite Image Fusion in Various Domains

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Abstract— *In order to find out the fusion algorithm which is best suited for the panchromatic and multispectral images, fusion algorithms, such as PCA and wavelet algorithms have been employed and analyzed. In this paper, performance evaluation criteria are also used for quantitative assessment of the fusion performance. The spectral quality of fused images is evaluated by the ERGAS and Q4. The analysis indicates that the DWT fusion scheme has the best definition as well as spectral fidelity, and has better performance with regard to the high textural information absorption. Therefore, as the study area is concerned, it is most suited for the panchromatic and multispectral image fusion. an image fusion algorithm based on wavelet transform is proposed for Multispectral and panchromatic satellite image by using fusion in spatial and transform domains. In the proposed scheme, the images to be processed are decomposed into sub-images with the same resolution at same levels and different resolution at different levels and then the information fusion is performed using high-frequency sub-images under the Multi-resolution image fusion scheme based on wavelets produces better fused image than that by the MS or WA schemes..*

***Keywords*— Wavelet transform, fusion algorithm.**

I. INTRODUCTION

With the recent rapid developments in the field of sensing technologies multi-sensor systems have become a reality in a growing number of fields such as remote sensing, medical imaging, machine vision and the military applications for which they were first developed. The result of the use of these techniques is a great increase of the amount of data available. Image fusion provides an effective way of reducing this increasing volume of information while at the same time extracting all the useful information from the source image

1. OVERVIEW

Remote sensing can be defined as any process whereby information is gathered about an object, area or phenomenon without being in contact with it. Our eyes are an excellent example of a remote sensing device. We are able to gather information about our surroundings by gauging the amount and nature of the reflectance of visible light energy from some external source (such as the sun or a light bulb) as it reflects off objects in our field of view. Contrast this with a thermometer, which must be in contact with the phenomenon it measures, and thus is not a remote sensing device.

1.2.1 TYPES OF REMOTE SENSING SOURCES

Remote sensing satellites generally obtain images from two kinds of sources:

1. ***Passive Sources***: These capture sun‘s radiation reflected from the imaging location. No radiation is generated by the source itself. Passive sources capture the following type of images:

A. Panchromatic: images captured in the visual frequency range.

B. Multispectral: Images captured over more than one spectral interval. Each individual image is usually of the same physical area but of different spectral band.

2. ***Active Sources***: These generate signal of a particular nature which is then reflected from the imaging location and captured back by the source. The received signal provides information about the reflectance properties of the imaging location. Some examples of active sources are:

a. Synthetic aperture radar: Working at higher radar frequencies, SAR is extremely useful in obtaining some information which may not be distinguishable by passive sources.

b. Light detection and ranging: LIDAR is generally used for altimeter applications.

1.2.2 TYPE OF REMOTE SENSING DATA

The images obtained from these different sources have spatial dependency but due to their different spectral quality, they also exhibit disparity in information content. The information contained in panchromatic images depends on the multispectral reflectivity of the target illuminated by sun light. SAR image intensities depend on the characteristics of the illuminated surface target as well as on the signal itself. The fusion of this disparate data contributes to the understanding of the objects observed. For many applications, images of the same location are obtained at different periods of times. This provides us with a large volume of images with different temporal, spectral and spatial resolution. Image fusion is usually performed on following sets:

1. ***Panchromatic and Multispectral data***: Low-spatial-resolution multispectral images are fused with high

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resolution panchromatic data. The high resolution of the panchromatic images is preserved along with the information content from the multispectral data.

2. ***Panchromatic and SAR data***: panchromatic and SAR are usually able to provide complementary data due to their different nature of signal source. This disparity in data is exploited extensively to obtain meaningful maps for different applications such as topographical surveys, vegetation monitoring etc. In order to introduce redundancy into these critical systems, generally images are obtained from multiple sensors. Fusion can also be done using data from these different channels. This is generally done to improve the signal to noise ratio of the obtained signals.

1.2.3 IMAGE FUSION IN REMOTE SENSING

Even though advances in sensor technology have been able to provide very high quality imagery, certain natural conditions such as cloud cover and weather and reflectance properties of different objects limit the final quality of information gathered from the images. Image fusion thus plays an important role in realizing practically useful applications from the remote sensing data.

Remote sensing data is useful in various applications from monitoring growth of vegetation to detection of geographical border infiltration. The usefulness of remote sensing data is only as good as its use in the required application. If the resolution of the captured data is too low or the distortion in the data is too high, the data may be of no use in any application. Unfortunately in real-world conditions the resolution and distortion are generally worse than what the original hardware was designed for or what is required of a given applications. Image fusion plays a very important role in such cases. It is able to convert a combination of such data sets with low information content to a single data set of higher information content. ―Higher information content‖ is only meant in a semantic sense for a particular application.

1.2.4 APPLICATIONS OF IMAGE FUSION IN REMOTE SENSING

Image fusion has been extensively used in the past on remote sensing data for various applications. Some of them are :

1. ***Sharpening of images****:*

An image of higher spatial resolution may be reconstructed from images of lower resolution. It is important to note that interpolation of data to achieve higher resolution using multiple images with different information content is very different from mere visual enhancement by superimposition of images. Also, fusion of data from different channels of the same sensor is also done to achieve greater spatial resolution

2. ***Improving geometric corrections***

Images of the same location taken from different angles may create a problem in registration due to different appearance of control features in the images.

3. ***Providing stereo viewing capabilities for stereo photogrammetry***

3-D modelling of landscape features requires images of very high resolution and good spatial distinction and accuracy. This is possible with image fusion applications.

4. ***Enhancing features not fully visible in either of the single data alone***

In case of cloud cover or mist, some features may not be fully visible in one particular spectral band. Fusing multiple bands of data, features which appear disjoint in individual images may be joined and a more reliable map obtained.

5. ***Detect changes using multi-temporal data***

SAR data which is independent of weather conditions may be complemented by visual images to detect physical changes. Change detection using image differencing, taking ratio and using principal component analysis methods such as wavelets in multi-resolution environment

1.3 IMAGE DESCRIPTION

A visual representation (of an object or scene or person or abstraction) produced on a surface. Data representing a two dimensional scene. An image is an artifact, for example a two-dimensional picture, that has a similar appearance to some subject usually a physical object or a person. A digital image is restricted in both its spatial coordinates and in its allowed intensities. Their positions and intensities are represented with discrete values, or elements. The discrete elements that make up a digital image are called picture, elements, or pixels.

A digital image is composed of pixels arranged in a rectangular array with a certain height and width. Each pixel may consist of one or more bits of information, representing the brightness of the image at that point and possibly including color information encoded as RGB triples. Images are usually taken from the real world via a digital camera, frame grabber, or scanner; or they may be generated by computer, e.g. by ray tracing software. The image of a function is the set of values obtained by applying the function to all elements of its domain. Practically everything around us involves images and image processing.

An image can be defined as a two-dimensional signal (analog or digital), that contains intensity (gray scale), or color information arranged along an x and y spatial axis. An image as defined in the ―real world‖ is considered to be a function of two real variables, for example, I(x,y) with as the amplitude (e.g. brightness) of the image at the real coordinate position (x,y).Modern digital technology

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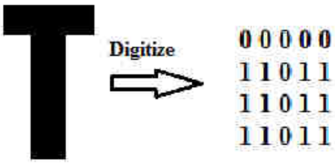
has made it possible to manipulate multi-dimensional signals with systems that range from simple digital circuits to advanced parallel computers.

The goal of this manipulation can be divided into three categories: Trivial Example;

Let 0 represent Black. Let 1 represent White.



The acquisition of a digital image is a three step process

1) Sample and quantize position
2) Quantize intensity for each quantized position
3) Conversion to binary digits, encoding

1) Sample and quantize: Make intensity readings at evenly spaced locations in both the *x* and *y* directions Visualized by placing an evenly spaced grid over the analog image.

2) Quantize Intensity: quantize the sampled values of intensity to arrive at a signal that is discrete in both position and amplitude.

3) Encoding: Convert data to binary form.

The process of analog to digital signal conversion is completed by encoding the quantized values into a binary sequence.

1.3.1 DIGITAL IMAGES TYPES

The images types we will consider are: binary, gray-scale, color and multispectral.

1. Binary Images

Binary images are the simplest type of images and can take on two values, typically black and white, or 0 and 1. A binary image is referred to as a 1bit image because it takes only 1 binary digit to represent each pixel. These types of images are frequently used in applications where the only information required is general shape or outline, for example optical character recognition

2. Gray Scale Image

Once a gray scale image has been captured and digitized, it is stored as a two- dimensional array (a matrix) in computer memory. Each element contains the quantized intensity, a value ranging from 0 to 255

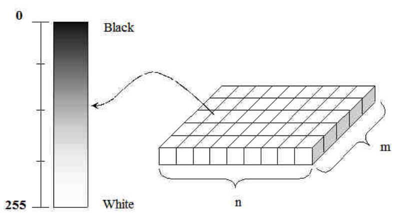


Fig. 1.1: Gray Scale Image

3. Color Image

- To digitize a gray scale image, we look at the overall intensity level of the sensed light and record as a function of position.
- To digitize a color image the intensities of each of the three primary colors must be detectable of the incoming light.
- One way to accomplish this is to filter the light sensed by the sensor so that it lies within the wavelength range of a specific color.
- We can detect the intensity of that specific color for that specific sample location.
- Note the three primary colors are red, green, and blue. They are defined as primary because any color of light consists of a combination of frequencies contained in the three "primary" color ranges an example of quantizing a color image consider a computer imaging systems that utilizes 24 bit color.
- For 24 bit color each of the three primary color intensities is allowed one byte of storage per pixel for a total of three bytes per pixel.
- Each color has an allowed numerical range from 0 to 255, for example 0=no red, 255=all red.
- The combinations that can be made with 256 levels for each of the three primary colors amounts to over 16 million distinct colors ranging from black (R,G,B) = (0,0,0) to white (R,G,B) = (255,255,255).
- Most computers store color digital image information in three dimensional arrays. The first two indexes in this array specify the row and column of the pixel and the third index specifies the color "plane" where 1 is red, 2 is green, and 3 is blue.

4. Multispectral Images

Multispectral images contain information outside the normal human perceptual range. This may include infrared, ultraviolet, Xray, acoustic or radar data. These are not images in the usual sense because the information represented is not directly visible by the human system. However, the information is often represented in visual form by mapping the different spectral bands to RGB components such as Thematic Mapper and Multi Spectral Scanner images.

1.3.2 IMAGE CHARACTERISTICS

Images may be two-dimensional, such as a photograph, screen display, and as well as a three-dimensional, such as a statue or hologram. They may be captured by optical devices such as cameras, mirrors, lenses, telescopes, microscopes, etc. and natural objects and phenomena, such as the human eye or water surfaces. The word image is also used in the broader sense of any two-dimensional figure such as a map, a graph, a pie chart, or an abstract painting. In this wider sense, images can also be rendered manually, such as by drawing, painting, carving, rendered automatically by printing or computer graphics technology, or developed by a combination of methods, especially in a pseudo-photo graph. A volatile image is one that exists only for a short period of time. This may be a reflection of an object by a mirror, a projection of a camera obscure, or a scene displayed on a cathode ray tube. A fixed image, also called a hard copy, is one that has been recorded on a material object, such as paper or textile by photography or digital processes.

A mental image exists in an individual's mind: something one remembers or imagines. The subject of an image need not be real; it may be an abstract concept, such as a graph, function, or "imaginary" entity. For example, Sigmund Freud claimed to have dreamed purely in aural-images of dialogs. The development of synthetic acoustic technologies and the creation of sound art have led to a consideration of the possibilities of a sound image made up of irreducible phonic substance beyond linguistic or musicological analysis.

A still image is a single static image, as distinguished from a moving image .This phrase is used in photography, visual media and the computer industry to emphasize that one is not talking about movies, or in very precise or pedantic technical writing such as a standard.

1.4 IMAGE FUSION

Information Fusion is a naturally occurring phenomenon in most biological systems. Data from various sources are merged in order to make optimal decisions. International society of information fusion aptly defines it as – ―Information fusion encompasses the theory, techniques and tools conceived and employed for exploiting the synergy in the information acquired from multiple sources such that the resulting decision or action is in some sense better than would be possible if any of these sources were used individually without such synergy exploitation ―Image Fusion is a similarly inspired effort to merge relevant visual data sets which are dependent and yet have disparity to certain extent in order to come up with a smaller data set apt for a better semantic interpretation of data for a given application.

1.4.1 IMAGE FUSION METHODS

Some standard algorithms for the fusion of satellite images can be described shortly as follows:

- Principal Component Analysis (PCA)-based
- Discrete Wavelet Transform (DWT)-based

Principal Components Analysis (PCA)

PCA is a general statistical technique that transforms multivariate data with correlated variables into one with uncorrelated variables. These new variables areobtained as linear combinations of the original variables. PCA has been widely used in image encoding, image data compression, image enhancement and image fusion. In the fusion process, PCA method generates uncorrelated images (PC1, PC2…PCn, where n is the number of input multispectral bands). The first principal component (PC1) is replaced with the panchromatic band, which has higher spatial resolution than the multispectral images. Afterwards, the inverse PCA transformation is applied to obtain the image in the RGB colour model.

Wavelet Transform (WT)

In the fusion methods based on wavelet transform, the images are decomposed into pyramid domain, in which coefficients are selected to be fused. The two source images are first decomposed using wavelet transform. Wavelet coefficients from MS approximation sub band and PAN detail sub bands are then combined together, and the fused image is reconstructed by performing the inverse wavelet transform. Since the distribution of coefficients in the detail sub bands have mean zero, the fusion result does not change the radiometry of the original multispectral image. The simplest method is based on the selection of the higher value coefficients, but various other methods have been proposed in the literature.

1.5 QUALITY ASSESMENT

Quality refers to both the spatial and spectral quality of images (Wald, 1997). Image fusion methods aim at increasing the spatial resolution of the MS images while preserving their original spectral content. The evaluation of the fusion results is based on the quantitative criteria including spectral and spatial properties.The spectral quality of fused images is evaluated by the Deviation Angle, Spectral Angle, Correlation Index, ERGAS, Q4 and RMSE

II. IMAGE FUSION

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 (like multi-sensor, multi-focus and multi-modal images). Image fusion is the process of combining relevant information from two or more images into a single image. The resulting image will be more informative than any of the input images.

Image fusion can synthesize many images from different sensors into a picture which can meet specific application by using a mathematical model. It can effectively combine the advantages from different images and improve the analysis ability. For example, in multi-focus imaging one or more objects may be in-focus in a particular image, while other objects in the scene may be in focus in other images. For remotely sensed images, some have good spectral information whereas others have high geometric resolution. In the arena of biomedical imaging, two widely used modalities, namely the magnetic resonance imaging (MRI) and the computed tomography (CT) scan do not reveal identically every detail of brain structure. While CT scan is especially suitable for imaging bone structure and hard tissues, the MR images are much superior in depicting the soft tissues in the brain that play very important roles in detecting diseases affecting the skull base. These images are thus complementary in many ways and no single image is totally sufficient in terms of their respective information content. The advantages these images may be fully exploited by integrating the complementary features seen in different images through the process of image fusion that generates an image composed of features that are best detected or represented in the individual images. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics.

For example, in multi-focus imaging one or more objects may be in-focus in a particular image, while other objects in the scene may be in focus in other images. For remotely sensed images, some have good spectral information whereas others have

high geometric resolution. In multi focus imaging first images is registered to avoid large misalignments. Each image is tiled with overlapping neighborhoods. Then, for each region the tile that corresponds to the best focus is chosen to construct the multi-focus image. In the arena of biomedical imaging, two widely used modalities, namely the magnetic resonance imaging (MRI) and the computed tomography (CT) scan do not reveal identically every detail of brain structure. While CT scan is especially suitable for imaging bone structure and hard tissues, the MR images are much superior in depicting the soft tissues in the brain that play very important roles in detecting diseases affecting the skull base. These images are thus complementary in many ways and no single image is totally sufficient in terms of their respective information content. The advantages these Images may be fully exploited by integrating the complementary features seen in different images through the process of image fusion that generates an image composed of features that are best detected or represented in the individual images. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics.

Image fusion is a tool for integrating a high-resolution panchromatic image with a multispectral image, in which the resulting fused image contains both the high-resolution spatial information of the panchromatic image and the color information of the multispectral image. Wavelet transformation, originally a mathematical tool for signal processing, is now popular in the field of image fusion. Recently, many image fusion methods based on wavelet transformation have been published. The wavelets used in image fusion can be categorized into three general classes: Orthogonal, Biorthogonal and No orthogonal. Although these wavelets share some common properties, each wavelet leads to unique image decomposition and a reconstruction method which leads to differences among wavelet fusion methods.

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. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. Fusion techniques include the simplest method of pixel averaging to more complicated methods such as principal component

analysis and wavelet transform fusion. Several approaches to image fusion can be distinguished, depending on whether the images are fused in the spatial domain or they are transformed into another domain, and their transforms fused.

2.1 IMPORTANCE OF IMAGE FUSION

Image Fusion is a framework where a composite image can be produced, that contains enhanced or simply better information about the target or scene compared to individual source images. Image Fusion had its beginning with the concept of simply averaging the intensities of the corresponding pixels of the set of input images, thus producing a fused image. A lot of advancements have happened in the field of image fusion since then employing advanced methods like Discrete Wavelet Transforms and Pyramidal Methods to fuse images. Multisensor data fusion has become a discipline to which more and more general formal solutions to a number of application cases are demanded. Several situations in image processing simultaneously require high spatial and high spectral information in a single image; especially in the field of remote sensing. However, the instruments are not capable of providing such information either by design or because of observational constraints. One possible solution for this is data fusion. Image Fusion techniques, though initially developed as an image quality enhancement technique, finds practical application in medical field and satellite imaging. The concept of multivariate image fusion now promotes research into fusing simple optical images, medical images and satellite images ranging through the multi spectra. For example, in

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satellite imaging, two types of images are available. Panchromatic image acquired by satellites is transmitted with the maximum resolution available and the multispectral data are transmitted with coarser resolution. This will be usually, two or four times lower. At the receiver station, the panchromatic image is merged with the multispectral data to convey more information. Many methods exist to perform image fusion. The very basic one is the high pass filtering technique. Later techniques are based on DWT, uniform rational filter bank, and pyramidal methods.

A broad list of applications of image fusion can be the following:

1. Image Classification
2. Aerial and Satellite imaging
3. Medical imaging
4. Robot vision
5. Concealed weapon detection

2.2 PROCESSING LEVELS OF IMAGE FUSION

Fusion of images is a process of identifying useful information content and combining them efficiently to make the final image more meaningful for a particular application.

Depending on the level at which the classification of useful data is done, images may be fused at the following levels:

1. Signal level
2. Pixel level
3. Feature level
4. Decision level

Fusion of same redundant data from different sensors is generally done to improve the signal to noise ratio and thus it can be categorized as an example of signal level fusion. Diversity combining is another kind of a signal level fusion.

At pixel level, fusion is done only on the basis of the intensity value of the pixels at particular points. At times neighbourhood property of pixel values may also be used for combining the images. Most colour-transform based fusion techniques such as IHS and HSV transform fall under this category. Many techniques fall between the pixel and feature level.

Techniques such as principal component analysis and multi-resolution analysis extract details of an image and perform fusion in a different domain. This leads to enhancement of the image along the required components of the image. Thus, to certain extent, this involves recognition of distinct features in the image. These features may not correspond to any particular spatial features but are generally at a broader scale than pixels.

Feature level fusion requires individual features to be identified by object recognition schemes.

Decision level fusion occurs at higher levels of abstractions by combining results from multiple algorithms to yield a final fused decision.

2.3 FUSION TECHNIQUES

At sub-feature level, many fusion techniques have been developed and are currently in use. In general, fusion techniques may be classified in either of the following categories

1. Colour based techniques
2. Statistical/Numerical techniques

Colour based techniques are important because the colour represent the band of frequencies reflected from the imaging location. This provides a human vision perception to the problem. Colour based techniques include transformations such as IHS and HSV.

Statistical approaches are developed on the basis of channel statistics including correlation and filters. Numerical methods follow arithmetic operations such as image differencing and ratios. Sophisticated approaches may be a combination of statistical and numerical methods such as wavelets in multi-resolution environment.

The most common form of transform image fusion is wavelet transform In common with all transform domain fusion techniques the transformed images are 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 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:

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

The process is as shown below:

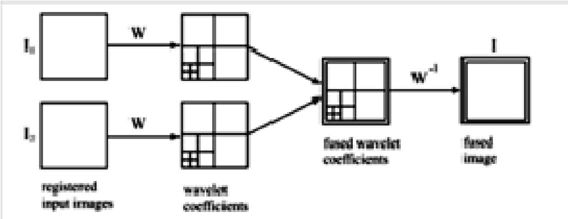

Fig. 2.1: DWT Image Fusion Process flow diagram.

2.4 IMAGE FUSION METHODS

Image fusion methods can be broadly classified into two - spatial domain fusion and transform domain fusion.

The fusion methods such as averaging method, Brovey method, principal component analysis (PCA) and high pass filtering based technique are examples of spatial domain fusion methods. Here the high frequency details are injected into upsampled version of MS images. The

disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image. Spectral distortion becomes a negative factor while we go for further processing, such as classification problem, of the fused image. The spatial distortion can be very well handled by transform domain approaches on image fusion. The multiresolution analysis has become a very useful tool for analyzing remote sensing images. The discrete wavelet transform has become a very useful tool for fusion. Some other fusion methods are also there, such as pyramid based, curvelet transform based etc. These methods show a better
performance in spatial and spectral quality of the fused image compared to other spatial methods of fusion.
There are two domains of fusion methods. They are

Spatial domain fusion

- Weighted pixel averaging
- Principal component analysis
- Intensity Hue Saturation

Transform domain fusion

- Laplacian pyramid
- Curvelet transform
- Discrete wavelet transform (DWT)

In this we use some standard algorithms for the fusion of satellite image can be described shortly as follows:

- Principal Component Analysis (PCA)-based
- Discrete Wavelet Transform (DWT)-based

2.5 FUSION CATEGORIES

1. Multi-modal fusion

These images coming from different sensors (visible and infrared, CT and NMR, or panchromatic and multispectral satellite images).

2. Multi-focus fusion

These images of a 3D scene taken repeatedly with various focal lengths.

3. Multi-view fusion

These or from the same modality and taken at the same time but from different view-points.

4. Multi-temporal fusion

This fusion of images taken at different times in order to detect changes between them or to synthesize realistic images of objects which were not photographed in a desired time.

2.6 APPLICATIONS OF IMAGE FUSION

Image fusion finds application in a very wide range of areas involving image processing. Some of the areas which find critical application of image fusion are as the following.

1. Intelligent robots

- Require motion control, based on feedback from the environment from visual, tactile, force/torque, and other types of sensors
- Stereo camera fusion
- Intelligent viewing control
- Automatic target recognition and tracking

2. Medical image

- Fusing X-ray computed tomography (CT) and magnetic resonance (MR) images
- Computer assisted surgery
- Spatial registration of 3-D surface

3. Manufacturing

- Electronic circuit and component inspection
- Product surface measurement and inspection
- non-destructive material inspection
- Manufacture process monitoring
- Complex machine/device diagnostics
- Intelligent robots on assembly lines

4. Military and law enforcement

- Detection, tracking, identification of ocean (air, ground)target/event
- Concealed weapon detection
- Battle-field monitoring
- Night pilot guidance

5. Remote sensing

Using various parts of the electro-magnetic spectrum
Sensors: from black-and-white aerial photography to multi-spectral active microwave space-borne imaging radar. Fusion techniques are classified into photographic method and numerical method

2.7 IMAGE FUSION IN REMOTE SENSING

Even though advances in sensor technology have been able to provide very high quality imagery, certain natural conditions such as cloud cover and weather and reflectance properties of different objects limit the final quality of information gathered from the images. Image fusion thus plays an important role in realizing practically useful applications from the remote sensing data.
Remote sensing data is useful in various applications from monitoring growth of vegetation to detection of geographical border infiltration. The usefulness of remote sensing data is only as good as its use in the required application. If the resolution of the captured data is too low or the distortion in the data is too high, the data may be of no use in any application. Unfortunately in real-world conditions the resolution and distortion are generally worse than what the original hardware was designed for or what is required of a given applications. Image fusion plays a very important role in such cases. It is able to convert a combination of such data sets with low information content to a single data set of higher information content. ―Higher information content‖ is

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only meant in a semantic sense for a particular application.

With the availability of multisensor, data in many field such as remote sensing medical imaging, machine vision and military applications, sensor fusion has emerged as a new and promising research area.

Multisensor data often presents complementary information about the region surveyed, so image fusion provides an effective method to enable comparison and analysis of such data. The goal of image fusion is to create new images that are more suitable for the purposes of human visual perceptions object detection and target recognition. The use of multisensory data such as visible and infrared images has led to increased recognition rate in application such as automatic target recognition.

The sensor image fusion systems are classified as

1. Single sensor image fusion systems

2. Multi sensor image fusion systems

2.7.1 SINGLE SENSOR IMAGE FUSION SYSTEM

An illustration of a single sensor image fusion system is shown in Figure 2.1.

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 computer to do some task.

For example in object detection, a human operator searches the scene to detect objects such as intruders in a security area.

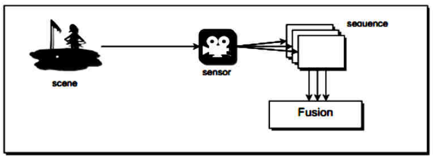

Fig. 2.2 Single Sensor Image Fusion Systems

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 illuminated environment such as daylight scenes but is not suitable for poorly illuminated situations found during night, or under adverse conditions such as in fog or rain.

2.7.2 MULTI-SENSOR IMAGEFUSION SYSTEM

Multi-sensor image fusion systems overcome the limitations of a single sensor vision system by combining the images from these sensors to form a composite image. Figure 2.2 shows an illustration of a multi-sensor image fusion system. In this case, an infrared camera is supplementing the digital camera and their individual images are fused to obtain a fused image. This approach overcomes the problems referred to before, while the digital camera illuminated ones.

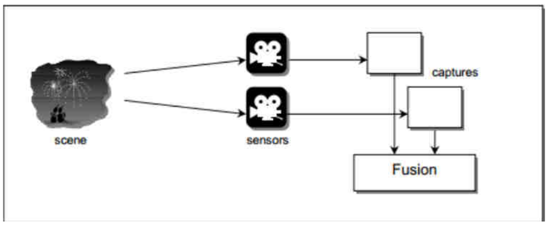

Figure 2.2 Multi sensors Image Fusion System

III. SYSTEM DESIGN&ANALYSIS

3.1 Standard Methods

This system contains some standard algorithms for the fusion of satellite images can be described shortly as follows:

• Principal Component Analysis (PCA)-based

• Discrete Wavelet Transform (DWT)-based

3.1.1 PRINCIPAL COMPONENTS ANALYSIS (PCA)

PCA is a general statistical technique that transforms multivariate data with correlated variables into one with uncorrelated variables. These new variables are obtained as linear combinations of the original variables. PCA has been widely used in image encoding, image data compression, image enhancement and image fusion. In the fusion process, PCA method generates uncorrelated images (PC1, PC2…PCn, where n is the number of input multispectral bands). The first principal component (PC1) is replaced with the panchromatic band, which has higher spatial resolution than the multispectral images. Afterwards, the inverse PCA transformation is applied to obtain the image in the RGB color model.

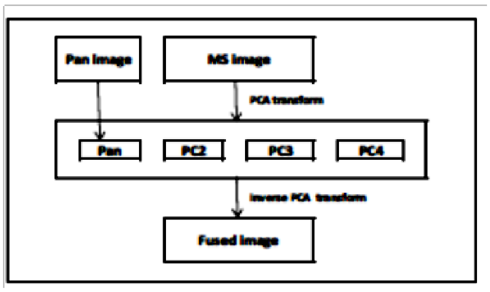

Fig. 3.1 PCA Block diagram

3.1.2 Wavelet Transform (WT)

In the fusion methods based on wavelet transform, the images are decomposed into pyramid domain, in which coefficients are selected to be fused. The two source images are first decomposed using wavelet transform. Wavelet coefficients from MS approximation sub band and PAN detail sub bands are then combined together, and the fused image is reconstructed by performing the inverse wavelet transform. Since the distribution of

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coefficients in the detail sub bands have mean zero, the fusion result does not change the radiometry of the original multispectral image. The simplest method is based on the selection of the higher value coefficients, but various other methods have been proposed in the literature.

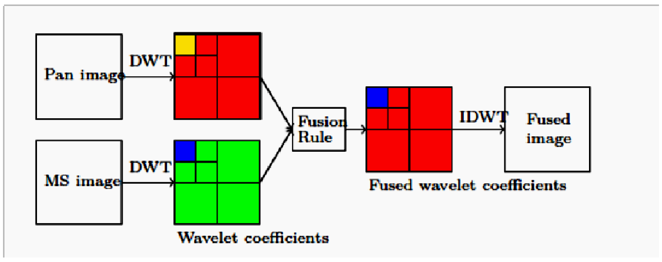

Fig. 3.2 Wavelet diagram

Detailed design of the proposed multi spectral image fusion approach work gives in depth picture of the most components described in the system architecture. In this section details and flow chart of each module has been described. The control flow is shown by the structure chart, the functional description of which are presented in the flow chart diagrams.

3.2 MODULE SPECIFICATION

The proposed system is designed with two fundamental modules as explained.

3.2.1 WAVELET BASED IMAGE FUSION

- Haar wavlet transform (DWT)
- Inverse Haar wavelet transforms (IDWT)
- Multi spectral Image fusion

3.2.2 PCA BASED IMAGE FUSION

Generation of principle components

- Pca2rgb space transformation
- Components fusion for enhancement.

3.3 STRUCTURE CHART

Structured flow chart gives overall strategy for structuring project. It gives details about each module evolve during detail design and coding. The modules and their design for this specific application are as shown in diagram.

A structure chart depicts

- The size and complexity of the system.
- Number of readily identifiable functions and modules within each function.
- Whether each identifiable function is a manageable entity or should be broken down into smaller components.

A structure chart is also used to associate the elements that comprise a run stream or thread. It is often developed as a hierarchical diagram, but other representations are allowable. The representation must describe the breakdown of the

configuration system into subsystems and the lowest manageable level. The structure chart of the project is as shown in the figure 3.1 and 3.2.

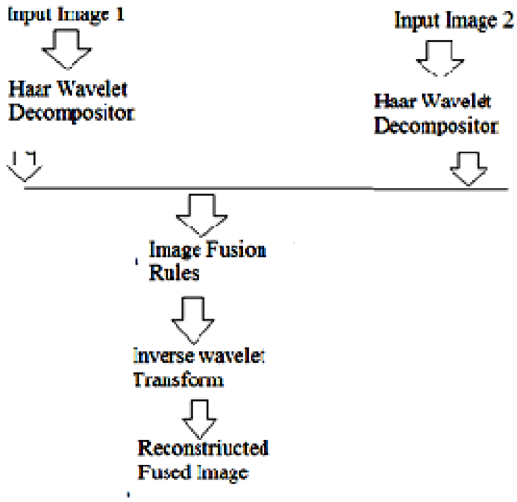

Fig. 3.3 structure chart 0f wave image fusion

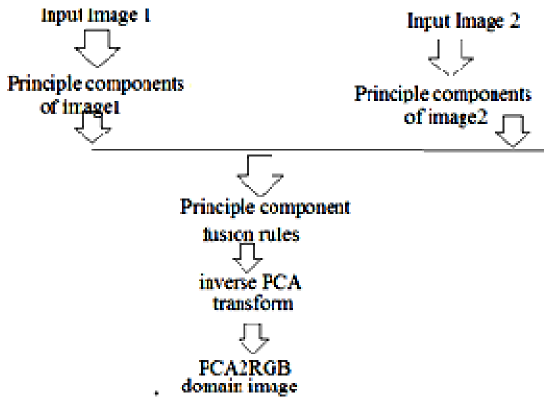

Fig. 3.4 Structure chart of PCA Based Image Picture

3.4 FLOW CHARTS

A flow chart is common type of notation that represents an algorithm or process, this diagrammatic representation give a step-by-step solution to a given problem. Flow charts are used in analyzing, designing, documenting or managing a process or program in various fields.

3.4.1 WAVELET BASED IMAGE FUSION

The flow Chart of Wavelet fusion is divided into Blocks A, B, C and D block.

Block A

Two images act as an input. The Two images are compared and evaluated. If the images are matched then they are processed for Block B. If the images are not matched an error message is obtained.

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Block B

The matched images are transformed into the wavelet domain.

Block C

In the wavelet domain choose the maximum co-efficient. The next function is the consistency function. The images are checked for the consistency. If the images are not consistent then consistency function is applied. If the images are consistent then the images are entered into the Block D.

Block D

The consistent image is next entered into the Block D. In Block D, the images are subjected to inverse wavelet transform. In this way the images are fused.

3.4.2 PCA BASED IMAGE FUSION

The flow Chart for PCA Based Image Fusion is divided into Blocks A, B, C and D block.

Block A

2 images act as an input. The 2 images are compared and evaluated. If the images are matched then they are processed for Block B. If the images are not matched an error message is obtained.

Block B

The matched images are transformed into the PCA Domain.

Block C

In the PCA Domain select luminance PCA component. The next function is the consistency function. The images are checked for the consistency. If the images are not consistent then consistency function is applied. If the images are consistent then the images are entered into the Block D.

Block D

The consistent image is next entered into the Block D. In Block D, the images are subjected to inverse PCA. In this way the images are fused.

3.5 PERFORMANCE EVALUATION

A number of statistical evaluation methods are used to measure after-fusion colour fidelity. The most commonly used measures selected for the study to compare the performance of image fusion methods are introduced in the following sections.

Performance evaluation of system can be analysed using various parameters.

• Deviation Index, RMSE
• Spectral Angle,
• Correlation Index,
• ERGAS and Q4

Here we use two metrics to measure quality. They are

□□**Relative Global Dimensional Synthesis Error (ERGAS)**

The formula for Relative Global Dimensional Synthesis

$$\mathrm{ERGAS} = 100\frac{h}{\ell}\sqrt{\frac{1}{n}\sum_{i=1}^{n}\frac{\mathrm{RMSE}_i^2}{\mathrm{MR}_i^2}}$$

where MRi is the mean radiance of the ith MS band, *h* is the spatial resolution of the high resolution image, l is the spatial resolution of the low resolution image. ERGAS offers a global depiction of the quality of radiometric distortion of the fused product. The lower the value of the RMSE index and the ERGAS index, the higher the spectral quality of the fused images.

□□**Universal Image Quality Index** (Q-average)

Quality Index (QI) is a metric that is used in order to evaluate the quality of monochrome images. Q4 is a generalization of QI by extending it to be calculated for hypercomplex numbers, or quaternions, representing the spectral pixel vectors. Q4 is defined as

$$\begin{aligned} \mathrm{Q4} &= \frac{4|\sigma_{\mathbf{rf}}|\cdot|\bar{\mathbf{r}}|\cdot|\mathbf{f}|}{(\sigma_{\mathbf{r}}^2+\sigma_{\mathbf{f}}^2)(|\bar{\mathbf{r}}|^2+|\bar{\mathbf{f}}|^2)} \\ &= \frac{|\sigma_{\mathbf{rf}}|}{\sigma_{\mathbf{r}}\sigma_{\mathbf{f}}}\;\frac{2|\bar{\mathbf{r}}|\cdot|\bar{\mathbf{f}}|}{|\bar{\mathbf{r}}|^2+|\bar{\mathbf{f}}|^2}\;\frac{2\sigma_{\mathbf{r}}\sigma_{\mathbf{f}}}{\sigma_{\mathbf{r}}^2+\sigma_{\mathbf{f}}^2} \end{aligned}$$

The first term measures the alignment of the spectral vectors and as such detects where radiometric distortion is accompanied by spectral distortions in a single factor. The second term measures the luminance distortion and the third measures the contrast distortion. Q4 factor is calculated over a window of M-by-M which is normally selected as M=16 or M=32. Q4 is averaged over the whole image to lead a global quality metric. Q4 is in the range [0*;* 1] where one represents the ideal fusion that is when the fused image and the reference image are identical.

IV. SOFTWARE REQUIREMENTS SPECIFICATION

In the Development of Satellite Image Enhancement Techniques using spatial and frequency domain methods to assess the Quality of the Fusion approach the common understanding between the user and developer is captured in requirements document.

4.1 OVERALL DESCRIPTION

This section provides a description of the general factors that affect the product and its requirements. This section provides a background for those, which are defined in detail in section 3.2, and makes them easier to understand. This section also deals with user characteristics, constraints and assumptions and dependency of the application.

4.1.1 PRODUCT PERSPECTIVE

The image fusion approach application is aimed towards the providing an image which is a fusion of 2 or more images retaining the important features from each of the image.

4.1.2 PRODUCT FUNCTIONS

The primary function of the product is to provide Multi Resolution Image Fusion based on wavelet transforms and PCA Transform. The product is developed as MATLAB programming language.

4.1.3 USER CHARACTERISTICS

- To use the application the user must have understanding of Image Processing Techniques and GUI design and the key terminologies used in the application.
- Must know the programming of language.

4.2 SPECIFIC REQUIREMENTS

Required Software and Hardware and their specifications are described as following:

4.2.1 SOFTWARE REQUIREMENTS

Software requirements for the implementation and testing

- Operating System : Windows XP/07/Vista
- Language : MATLAB programming language
- Software Packages : MATLAB 7.0 and above

4.2.2 HARDWARE REQUIREMENTS

- Processor : INTEL Core 2 Duo 32 bit
- RAM : 1 GB
- Input device : Keyboard and mouse
- Output device : Color monitor Network hardware : Network Interface Card

4.2.3 CORE TOOLS AND TECHNOLOGIES

This section covers the complete development matrix. It identifies the technology elements with guidelines and specifications for specific implementations. The core tools and technologies elements used in developing the project is as shown in table 2.1.

MATLAB includes development tools that help to implement the algorithm efficiently. These include the following:

MATLAB Editor and Debugger - Provides standard editing and debugging features, such as setting breakpoints and single stepping

V. MODULES AND IMPLEMENTATION

5.1 WAVELET TRANSFORM (WT)

In the fusion methods based on wavelet transform, the images are decomposed into pyramid domain, in which coefficients are selected to be fused. The two source images are first decomposed using wavelet transform. Wavelet coefficients from MS approximation sub band and PAN detail sub bands are then combined together, and the fused image is reconstructed by performing the inverse wavelet transform. Since the distribution of coefficients in the detail sub bands have mean zero, the fusion result does not change the radiometry of the original multispectral image. The simplest method is based on the selection of the higher value coefficients, but various other methods have been proposed in the literature.

The schemes used to decompose the images are based on decimated and un decimated algorithms. In the decimated algorithm, the signal is down-sampled after each level of transformation. In the case of a two-dimensional image, down-sampling is performed by keeping one out of every two rows and columns, making the transformed image one quarter of the original size and half the original resolution. In the lower level of decomposition, four images are produced, one approximation image and three detail images. The decimated algorithm is not shift-invariant, which means that it is sensitive to shifts of the input image. The decimation process also has a negative impact on the linear continuity of spatial features that do not have a horizontal or vertical orientation. These two factors tend to introduce artifacts when the algorithm is used in applications such as image fusion.

On the other hand, the un decimated algorithm addresses the issue of shift-invariance. It does so by suppressing the down-sampling step of the decimated algorithm and instead up sampling the filters by inserting zeros between the filter coefficients. The un decimated algorithm is redundant, meaning some detail information may be retained in adjacent levels of transformation. It also requires more space to store the results of each level of transformation and, although it is shift-invariant, it does not resolve the problem of feature orientation.

Here DWT transform is used in wavelet fusion Method.

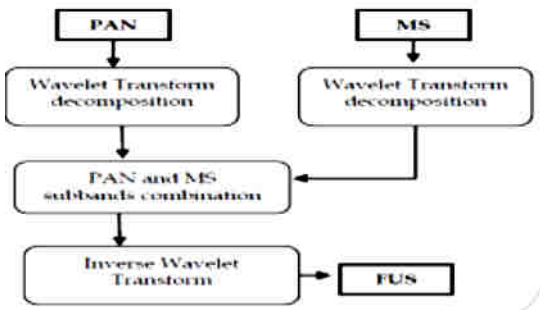

Fig. 5.1. Block diagram of the Wavelet fusion method.

Implementation of DWT wavelet fusion is explained as below:

Step 1: Assuming that the panchromatic image and multi spectral image has been registered, apply the histogram match process between panchromatic image and different bands of the multi spectral image respectively, and obtain three new panchromatic images (PAN R, PAN G and PAN B).

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Step 2: Use the wavelet transform to decompose new panchromatic images and different bands of multispectral image respectively to obtain approximation and detail components. The wavelet used for fusion is ‗db4‘ orthogonal wavelet.

Step 3: Add the detail images of the decomposed pan image at different levels to the corresponding details of different bands in the multi spectral image and obtain the new details component in the different bands of the multi spectral image.+

Step 4: Perform the inverse Discrete Wavelet transform on the bands of multi spectral images, respectively, and obtain the fused image.

5.1.2 DECOMPOSITION OF DWT

The following figures show the structures of 2-D DWT with 3 decomposition levels:

After one level of decomposition, there will be four frequency bands, namely Low-Low (LL), Low-High (LH), High-Low (HL) and High-High (HH). The next level decomposition is just apply to the LL band of the current decomposition stage, which forms a recursive decomposition procedure. Thus, an N-level decomposition will finally have *3N+1* different frequency bands, which include *3N* high frequency bands and just one LL frequency band. The 2-D DWT will have a pyramid structure shown in the above figure. The frequency bands in higher decomposition levels will have smaller size.++

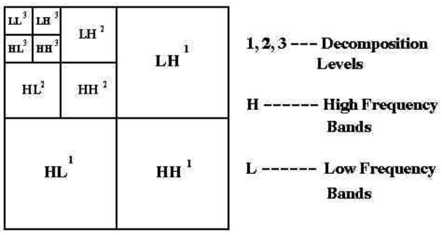
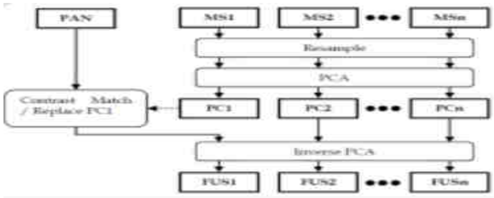


Fig. 5.2. Decomposition of DWT Levels

5.2 PRINCIPAL COMPONENTS ANALYSIS (PCA)

Figure 5.2 shows the PCA method of fusion. PCA is a general statistical technique that transforms multivariate data with correlated variables into one with uncorrelated variables. These new variables are obtained as linear combinations of the original variables. PCA has been widely used in image encoding, image data compression, image enhancement and image fusion. In the fusion process, PCA method generates uncorrelated images (PC1, PC2…PCn, where n isthe number of input multispectral bands). The first principal component (PC1) is replaced with the panchromatic band, which has higher spatial resolution than the multispectral images. Afterwards, the inverse PCA transformation is applied to obtain the image in the RGB color model. In PCA image fusion, dominant spatial information and weak color information is often a Problem. The first principal component, which contains maximum variance, is replaced by PAN image. Such replacement maximizes the effect of panchromatic image in the fused product. One solution could be stretching the principal component to give a spherical distribution.



Block diagram of PCA fusion method:

The following are the steps for implementation of PCA method:

Step1: Determine the Eigen value and Eigen vector of the matrix. Highest Eigen value will have PCA 1 component which represents the high frequency components like edge details.

Step2: Pan chromatic image is matched by first principle component.

Step3: First PCA of multi spectral image is replaced by matched PAN.

Step4: Perform inverse PCA transform to get the fused image. The main advantage of PCA is to transforms number of correlated variable into number of uncorrelated variables, this property can be used in image fusion But disadvantage in this is Spatial domain fusion image may produce spectral degradation.

5.2.1 PCA CONVERSION

The Principle Component Analysis (PCA) converts inter correlated multispectral bands into a set of uncorrelated components.

• The first band, which has the highest variance, is replaced by the panchromatic image.

• They are fused together by inverse PCA to obtain high-resolution pan sharpened image.

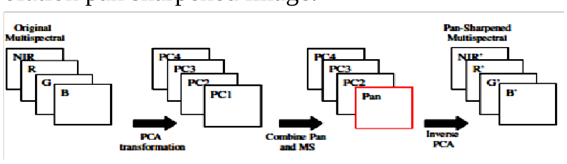


Fig. 5.4 PCA conversion of components

VI. RESULTS AND STATUS

In this work, an image fusion algorithm based on wavelet transform is proposed. In the proposed scheme, the images to be processed are decomposed into sub-images with the same resolution at same levels and different resolution at different levels and then the information fusion is performed using high-frequency sub-images under the Multi-resolution image fusion scheme based on wavelets produces better fused image than that by the MS or WA schemes. The use of both gradient and relative smoothness criterion ensures two fold effects:

• The gradient criterion ensures that edges in the images are included in the fused algorithm.

• The relative smoothness criterion ensures that the areas of uniform intensities are incorporated in the fused image thus; the effect of noise is minimized.

To understand the fusion process and evaluation of quality metrics, some screen shots of GUI‘s under image fusion working environment are given below.

Based on these we can understand fusion process and measure quality metrics of fusion algorithms. Depending on the values of quality metrics, we can understand which fusion method is best.

Qualities of fused images are spatial quality and spectral quality. The lower the value of RMSE and ERGAS, the higher the spectral quality of fused images.

6.1 IMAGE FUSION WORKING GUI DESIGN

The below image shows working environment of image fusion of panchromatic and multispectral images. Here we have taken satellite images. Panchromatic image contains more spatial resolution and MS image contains more spectral quality.

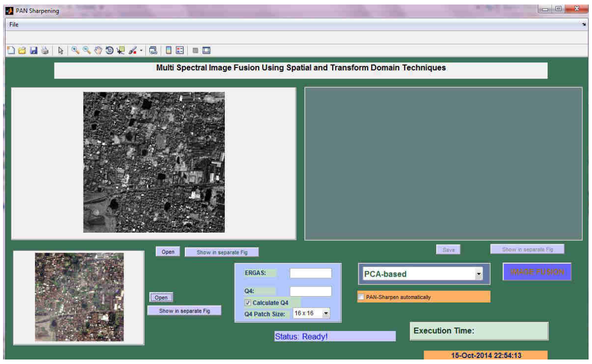


Fig. 6.1 Image fusion working environment

As shown in fig.6.1, when we click Open‘ button nearby image axes then images will be opened. After that we can select image fusion method and then the fusion button should be pressed. Then it processes the image fusion.c

6.2 WAVELET BASED IMAGE FUSION GUI

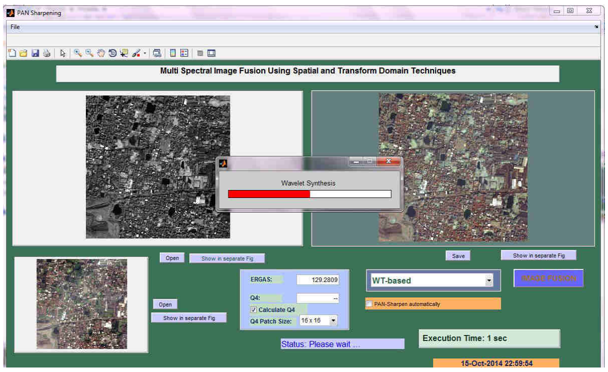


Fig. 6.2 Wavelet based image fusion

The figure 6.2 shows the GUI of Wavelet based image fusion. For this need to select the wavelet based fusion in pop-up button and press the image fusion button. Then it processes the WT based fusion and ERGAS&Q4 are calculated for the performance evaluation.

6.2.1 IMAGE FUSION RESULTANT GUI USING WAVELET

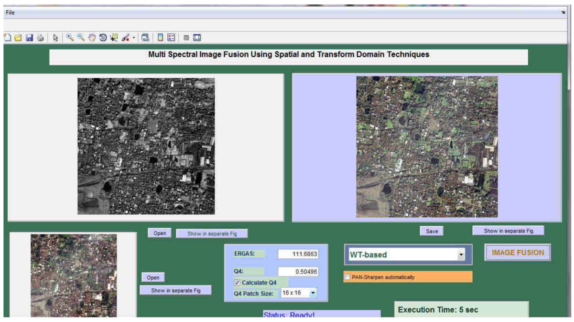


Fig. 6.3 Output Result of wavelet image fusion

The above figure shows the Output of WT based fusion. The fused image with high spatial resolution is appeared in another window and also quality metrics gives the value of WT fusion.

6.2.2 WAVELET IMAGE FUSION RESULTANT OUTPUT DIAGRAM

Figure

Fig. 6.4: Fused image of Wavelet image fusion

Figure 6.4 shows the fused satellite image of DWT image fusion and it has higher spatial resolution.

6.3 PCA BASED IMAGE FUSION GUI

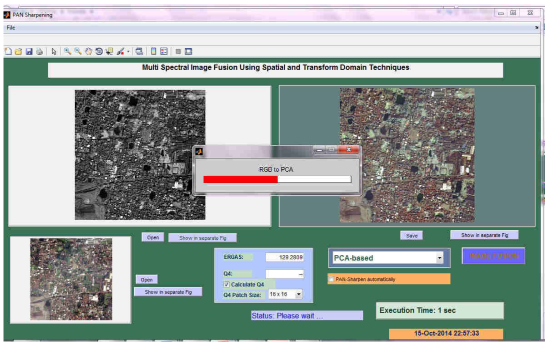


Figure 6.5: PCA based image fusion

Above Screenshot displays PCA based image fusion. In the Pop –Up button PCA-based is selected and further the fusion processed and quality of fusion will be calculated.

6.3.1 PCA BASED IMAGEFUSION RESULTANT OUTPUT GUI

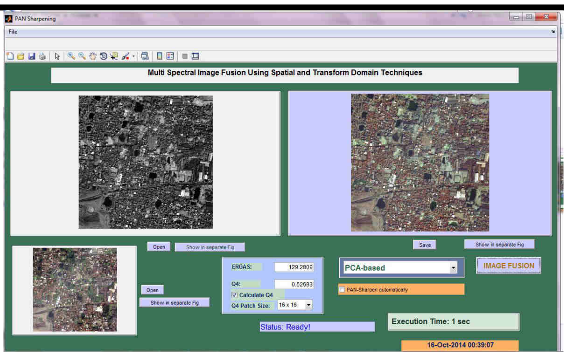


Fig. 6.6: Output of PCA based image fusion

This screenshot shows the Result of PCA-based fusion. It displays the fused image and performance of PCA also calculated.

6.3.2 FUSED OUTPUT IMAGE OF PCA BASED IMAGE FUSION

Fig. 6.7 Fused image of PCA image fusion

Figure 6.7 is the fused image of PCA based fusion. It also has more spatial quality and spectral quality.

6.4 PERFORMANCE RESULT OF FUSION METHODS

Table 6.1: Evaluation results of fusion techniques

Parameter	PCA Based Fusion		WT Based Fusion	
ERGAS	129.2809		111.6863	
Q4	8 by 8	0.43337	8 by 8	0.44466
	16 by 16	0.32693	16 by 16	0.34495

The above table describes that ERGAS value of DWT is lower than the PCA And Q4 of DWT is higher than the value of PCA.

VII. CONCLUSION

To preserve the spectral characteristics of the source multispectral image as well as the high spatial resolution characteristics of the source panchromatic image and suited for fusion of Panchromatic and Multispectral images. The problems of PCA dominant spatial information and weak color information can be solved. Therefore suited for visual interpretation, image mapping, and photogrammetric purposes wavelet Transform based on haar wavelet is the best method in retaining spectral property of the original image among the five used methods at the cost of low spatial information, Therefore are suited for digital classification purposes.

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