CHAPTER 1

INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

In the last two decades, the number of different Earth observation satellites and airborne sensors has increased significantly. The increasing availability of satellite imagery with significantly improved spectral and spatial resolution has offered greater potential for improved information extraction. These images, however, are not easily accessible due to the prohibitive cost and logistics (*viz.* clearance by government to the user). To overcome such limitations, we have to resort to techniques that utilize the available coarse (spatial and spectral) resolution images and extract more information about the earth features. This thesis is concerned with the generation and utilization of image fusion techniques that extract more and better information from the available multisensor sources.

The New Oxford dictionary of English gives the meaning of *fuse* as '*join or blend to form a single entity*' and *fusion* as '*the process or result of joining two or more things together to form a single entity*'.

Wald (1999) defines Data fusion as '*a formal frame work in which are expressed means and tools for the alliance of data originating from different sources*'. He adds that data fusion aims at obtaining information of greater quality: the exact definition of greater quality will depend upon the application.

Emphasizing the input of multisensor data, Hall (1997) defines data fusion as '*a process dealing with data and information from multiple sources to achieve refined/improved information for decision making*'.

Chavez (1991) also defines image fusion as '*the process where different multisensor and / or multiresolution image data are integrated together*'.

1.2 BACKGROUND

Analysts use remote sensing image to gain information about a target or land area that cannot be obtained by direct measurement. They use the information in the different images to infer the characteristics of the target. Each digital image is formed as an array of pixels where each pixel contains specific information about a surface feature. Spatial resolution is the clarity of the high frequency information of an image and it is interdependent with scale of the image. Spatial resolution is often expressed as the width of instantaneous field of view (IFOV) or one side of a pixel (picture element). The IFOV is the ground area sensed by a sensor at an instant in time (Lillesand and Kiefer 1994). Finer the IFOV, higher is the spatial resolution. Spectral resolution is defined as the width within the electromagnetic spectrum that can be detected by a band of a sensor. The narrower the spectral bandwidth, the higher the spectral resolution. Usually higher spectral resolution requires a larger IFOV, in order to maintain sufficient level of energy reaching the sensor. All factors held constant, a larger IFOV results in a larger measurement time over a given ground resolution cell and higher signal to noise ratio (SNR) (Lillesand and Kiefer 1994).

Panchromatic sensors usually have broader spectral bandwidth which allows finer spatial resolution by increasing SNR over a broad spectral band (Schowengerdt 1997). Thus, to increase either spectral or spatial resolution, one of the two must be sacrificed.

Multiresolution image fusion, also known as data merging, is an important aspect of digital image processing. Data fusion is an image processing technique that allows the analyst to circumvent the trade off between spatial and spectral resolution, and permit the preservation of fine resolution and spectral integrity. Image fusion enables users to integrate different image data sets and therefore increase their information contents (Carper et al 1990). Essentially two or more images of the same scene are combined to create a single image that contains best data characteristics of all the images used.

1.3 NEED FOR THE STUDY

There are many multi-sensor, multi-spatial resolution, multi-spectral and multi-temporal images currently available. The information content in each image data set, however, is limited due to the properties of the sensor source. Image and data fusion are the techniques to integrate these images and other data to obtain more and better information about an object or area than cannot be derived from the single sensor image data alone.

Table 1.1 A few of the previous works related to the present study

Low resolution image	High resolution image	Sharpening factor (Resolution Ratio)	Fusion technique implemented	Reference
MSS	SAR (airborne)	-	FCC	Daily et al 1979
Simulated from MSS-1 and MSS-4	MSS-2	5:1 & 3:1	HBF (High boost filter)	Schowengerdt 1980
TM	Aerial Photography	7:1	Image addition	Chavez 1986
SPOT-XS	SPOT-P	2:1	IHS	Carper et al 1990
TM	SPOT	3:1	IHS	Ehlers 1991
TM	SPOT	3:1	HBF, IHS, PCA	Chavez et al 1991
TM	ERS-SAR	3:1	FCC, PCA	Pohl 1995
TM	SPOT	3:1	Wavelet	Garguet Duport et al 1996
TM	SPOT	3:1	Wavelet	Yocky 1996
IRS-LISS-III	IRS-PAN	23.5:5.8	IHS, Fourier transform	Mohanty 1997
TM	SPOT	3:1	Wavelet	Li et al 1999
SPOT-XS	SPOT-P	2:1	ARSIS (Wavelet)	Ranchin and Wald 2000
ASTER-SWIR	ASTER-VNIR	2:1	Wavelet	Vani 2002

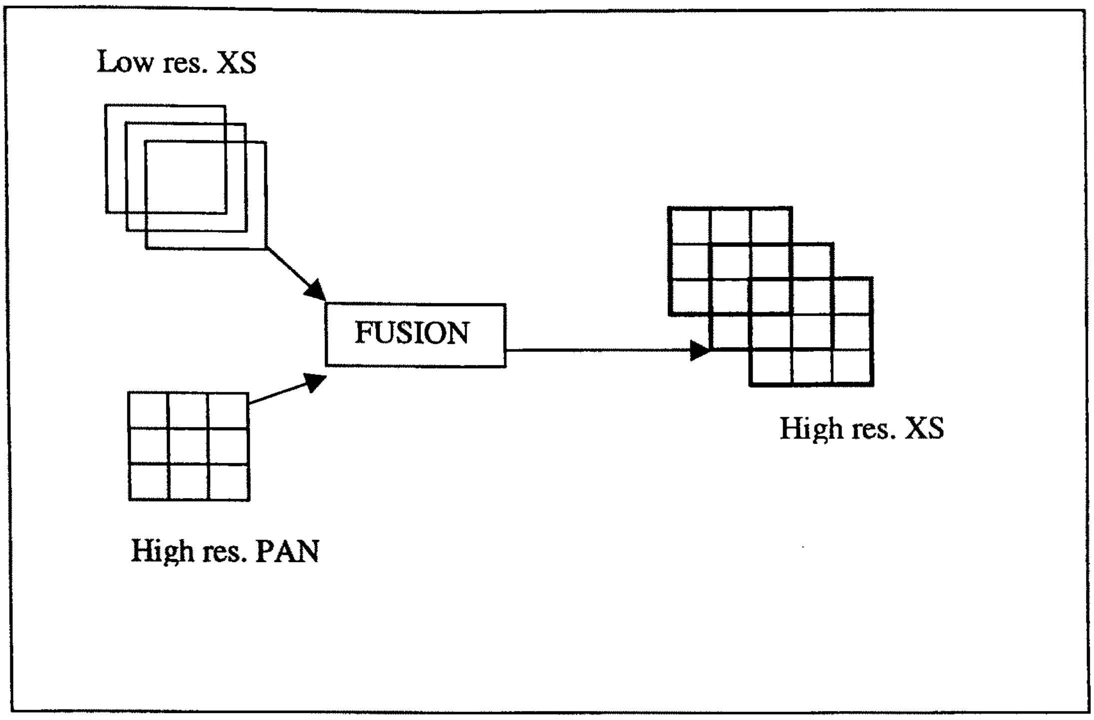
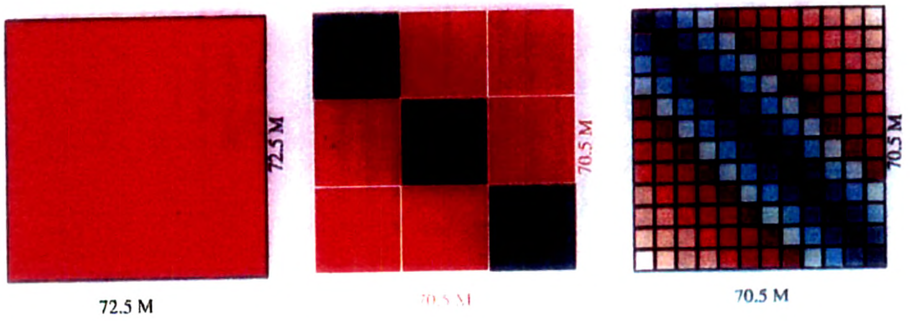


Figure 1.1 The fusion process

IRS LISS-III data has multispectral information but is of low spatial resolution (23.5m). While IRS PAN data has high (5.8m) resolution, it is panchromatic. Image fusion is an integrative processing technique that will fuse these two images together to result in a single image containing high spatial details of the PAN image and multispectral information of the LISS-III image. Figure 1.1 explains the process of image fusion.

A detailed explanation for the need for image fusion is given in Figure 1.2. It may be inferred from the Figure that the single pixel of LISS-I, which covers an area of 72.5m x 72.5m carries information about one landcover feature (vegetation) only. An approximately equal area (70.5m x 70.5m) is covered by nine 23.5m resolution LISS-III pixels. We may now infer that there are two classes within this area, namely, vegetation and water. On fusing the 23.5m LISS III (XS) image with 5.8m resolution PAN image, we obtain a 5.8m resolution, 144 pixel multispectral image. From this image it is inferred that there are 2 to 3 vegetation classes and 2 to 3 water classes. This information is certainly more in quantum and better in quality than the first two images, thus demonstrating the benefit of multisensor image fusion.



IRS 1A LISS-I
Resolution 72.5m

IRS 1C LISS-III
Resolution 23.5m

IRS 1C PAN +LISS-III
Resolution 5.8m

Figure 1.2 Graphical representation of the concept of multisensor image fusion

Fusion is possible because the bands in multispectral image have some degree of correlation. Also, the panchromatic image band typically overlaps with some of the multispectral bands.

The methods that have been used so far for fusion are the IHS (Intensity Hue Saturation) method, the PCA (Principal Component Analysis) method, the HPF (High Pass Filter) method, the WTA (Weighted Average) method, the Multiplicative method and the Brovey method. Some of these methods, considered as conventional techniques, are described in the Chapter 6. Due to the limitations of these techniques, certain recent methods which include the radiometric method, spherical coordinate method, wavelet transform method and influence factor modification fusion have been developed.

1.4 BENEFITS OF FUSION

Some of the benefits of image fusion are: it enhances the spatial resolution of multispectral image data sets, it sharpens the images, it improves classification accuracies of the image data, it improves the results of geometric corrections, it provides stereo viewing capabilities for stereo photogrammetry, it enhances certain features not visible in either of the single data alone, it complements data sets for improved mapping, it detects changes using multi-temporal data, it substitutes missing information in one image with signals from another sensor image (e.g clouds-VNIR, Shadows-SAR) and it replaces defective data (Fusetutor 1998).

The major scientific contribution of image fusion so far has been the increased cartographic potential of fused data sets. Image fusion has been used for a variety of mapping applications such as: to update topographic maps in the tropics (Pohl and Van Genderen 1995), to improve classification accuracy (Vani 2001a), for cartographic feature extraction (McKeown et al 1999), for 1:24000 scale mapping (Chavez 1986) and for geologic mapping in 1:24000 scale (Grasso 1993).

1.5 OBJECTIVES

For an image fusion method to be effective, the merged images should retain the high spatial resolution information from panchromatic data set while maintaining the basic spectral record of original multispectral data (Carper et al 1990). This thesis strives to achieve the standard set by Carper et al (1990) based on the following objectives.

- to evolve multisensor image fusion techniques and extract more information about landcover features from remote sensing images,
- timprove the interpretability of remote sensing images,
- to evaluate the quality of fused images and the techniques of fusion,
- to test the potential of fusion for different applications, and
- to assess role of fusion in aiding subpixel classification.

To achieve the above-mentioned objectives, several exercises were carried out in this study, and are presented as this thesis.

1.6 STRUCTURE OF THE THESIS

This thesis is divided into eight chapters. Chapter 1 gives the background information on image fusion, the need for fusion and its applications. In Chapter 2, a comprehensive review of the available literature about fusion is presented. Review of the available literature is also discussed throughout this thesis in the relevant sections. The implementation and the characteristics of conventional and wavelet image fusion techniques are presented in Chapter 3. In Chapter 4, the results of evaluation of the fused images and the performance of fusion approaches are presented. In this chapter, the results of visual and statistical comparison are presented, apart from the newly suggested classification accuracy and signature separability tools of evaluation. In Chapter 5, an experiment on fusion of images from different non-overlapping spectrum like VNIR, SWIR and microwave is presented and the resulting images are tested for different mapping applications. The role of image fusion in sub-pixel classification is explored in Chapter 6. The results of the experiments listed above are compiled and analysed in Chapter 7. The significant conclusions drawn from the experiments and the scope for further research are listed in Chapter 8.