Structural Feature Extraction from Satellite Images

Lizy Abraham[1], Dr.M.Sasikumar[2]

Abstract - Roads, buildings and bridges are the main structural features obtained from satellite images. Detection of clouds and shadows supports the extraction of these features. Different algorithms are available for the extraction of these features, depending on the availability of remotely sensed data. In this paper, a comparative study is done for different algorithms using different types of data.

Index Terms - Fuzzy inference, Multispec, Near Infrared, Pan Sharpened, Spatial resolution, Vegetation

1 INTRODUCTION

A few years ago, SPOT panchromatic image was the ultimate in high resolution satellite imaging with a spatial resolution of 10m [1]. Later in 1996, the Indian satellite IRS 1C improved the resolution further to 5.6m in their images. Another Indian satellite CARTOSAT promises 2.5m resolution. Now CARTOSAT 2B have less than 1m resolution and SPOT 5 cameras have 2.5m resolution. The US satellites IKONOS and Quickbird offers a resolution of 1m and 60cm respectively.

The availability of such high-resolution satellite imaging sensors provide a new data source for structural feature extraction. The very fine details in urban areas greatly facilitates the classification and extraction of features such as roads [2] buildings [3] and bridges [4]. The authors have done a study of detection of shadows and clouds to get a cloud/ shadow free image using high resolution satellite images [5, 6].

1.1 Types of Satellite Images

High-resolution satellite imaging sensors (IKONOS, Quickbird and SPOT) provide one band of panchromatic data of about 1m resolution and four bands of multispectral data of about 4m resolution. These images are produced in a variety of formats according to the needs of the application and data handling capabilities of the user. Different band combinations are available: panchromatic (black and white), multispectral, pan-sharpened (colour), or a bundle of panchromatic and multispectral imagery. Only three bands can be simultaneously displayed on computer monitors for visual interpretation.

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Common band combinations are natural colour with red-green-blue (RGB) displays and Colour Infra-Red (CIR) with NIR (Near Infrared) displayed as red, Red displayed as green, and Green displayed as blue. The image in Fig. 1 shows a Panchromatic (Gray scale) image having some trees and green areas. If the image is displayed in Natural Colour (RGB) combination, these green regions and trees can be seen as green colour itself. Also other areas have the same colour as we see with our naked eyes. But if the area is displayed in Colour-Infrared (CIR) combination, as the trees have high reflectance of infrared light, these areas can be seen as red colour. So for feature extraction processes using satellite images, Natural-colour is good for analyzing man-made objects such as roads, buildings and bridges. Colour-infrared combination, which is highly reflective in Near IR, is often used for detection of vegetation and camouflage.

The choice of which bands to use for each feature extraction problem (panchromatic, multispectral, or a combination of both) depends on the type of detection algorithm employed. Spatial detection will obviously require higher spatial resolution, whereas spectral detection (such as classification) will require greater spectral resolution.

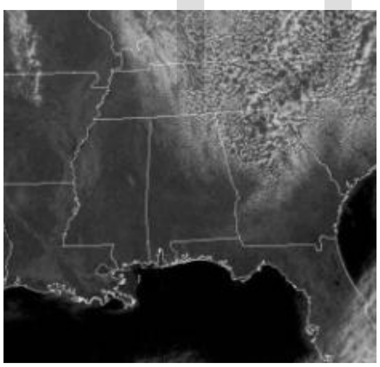
Fig. 1. Panchromatic (Gray scale) Image

2.0 Softwares for Processing Remote Sensed Data:

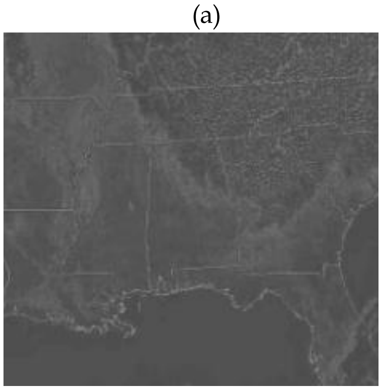
For spectral domain processing, we always prefer a Pan Sharpened Multi-Spectral satellite (PSMS) image, derived by pan sharpening from a low resolution(4m) multi-spectral (R,G,B,NIR) bands and high resolution (1m) panchromatic band data from a satellite sensor. Pan sharpening is a pixel level fusion technique used to increase the spatial resolution of the multi spectral image using spatial information from the high resolution panchromatic image while preserving the spectral information in the multispectral image. Thus the input PSMS image obtained will have a resolution of 1m with multispectral (R, G, B, NIR) bands. In this paper this is done using Multispec32 which is a freeware multispectral image data analysis system [7]. Multispec32 generates the .lan file of the PSMS image using high resolution panchromatic and low resolution multispectral satellite imagery. The resultant PSMS image has the same resolution as that of PAN image. We can also use other softwares like ENVI, ERDAS Imagine and PCI Geomatica for the purpose.

2.1 Elimination of Clouds

We have developed an algorithm for cloud detection and removal from satellite images [6]. The algorithm works well for both clouds and cloud-shadows and their compensation. Some of the results are shown in Fig. 2 and 3. But the problem is, as the method is intensity level processing, it fails for denser clouds.



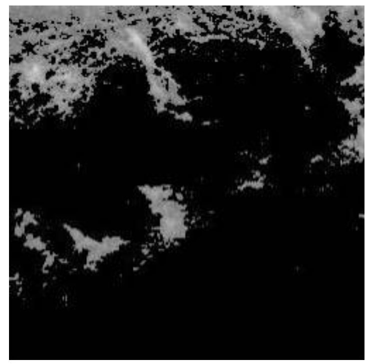
(a)



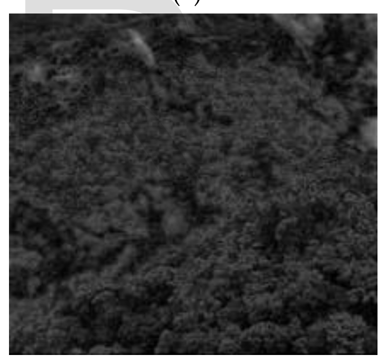
(b)

Fig. 2: (a) Visible Satellite Image of SE USA (b) Cloud Processed Image

(a)



(b)



(c)

Fig. 3: (a) RGB Aerial Image (b) Cloud Extracted image (c) Cloud Processed Image

In [8] some threshold tests are proposed for multispectral cloud detection which are given below:

IR10.8 . . . cold cloud test
VIS8 . . . bright cloud test (during day only)
VIS8 . . . bright cloud test (during day only)
IR10.8 - IR12.0 . . . high cloud test
IR8.7 - IR10.8 . . . cirrus cloud test
IR3.9 - IR12.0 . . . thin cirrus test (during night only)
IR10.8 - IR3.9 . . . low cloud and fog test
where,
Red channel = Difference IR12.0 - IR10.8
Green channel = Difference IR10.8 - IR3.9
Blue channel = Channel IR10.8

But for the case of structural feature extraction we have nothing to do with clouds; we only want to remove the clouds. So if the region has thick clouds better to discard that image and go for some other images of the same region. If the region has thin clouds the algorithm described in [6] can be used. But, if the region is near to north or south poles or mountain areas most of the images taken at any time may have the effect of clouds and if we want to get the structural features of that region, there is a rare possibility to get a cloud free image or an image having thin clouds. For these types of regions, intensity level processing fails and we have to go for spectral domain processing [8].

2.2 Shadow detection and removal

In high spatial resolution satellite images, shadows are usually cast by elevated objects such as buildings, bridges, and towers, especially in urban region. Shadows may cause loss of feature information, false colour tone and shape distortions of objects, which seriously affect the quality of images, and directly influence the object recognition process. Either in spectral domain or intensity domain the shadow detection method is not so easy. We have proposed a method in [5]. The results are shown in Fig. 4. Here an adaptive thresholding scheme based on mean values of panchromatic image is used.

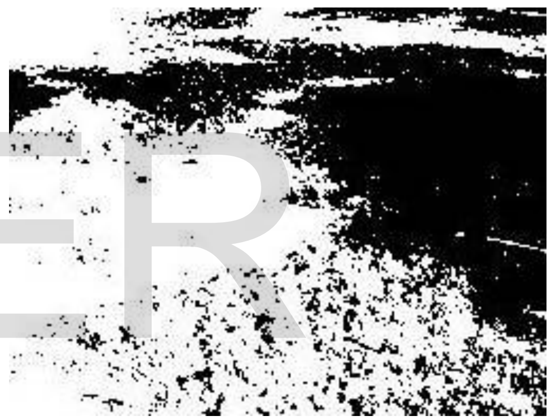
(a)

(b)

Fig. 4: (a) IKONOS Image of Petronas Twin Towers, Malaysia (b) Shadow Extracted Image

The distinction of colours between the shadows of buildings and water surface is still a challenge to the professionals [9]. We have developed a solution for this by considering variance values also [5]. For the removal of shadows, the algorithm applied for cloud shadows [6] can be used. The result obtained using [9] is shown in Fig. 5.

(a)



(b)

(c)

Fig. 5: (a) Aerial Image having Cloud-Shadows (b) Shadow Extracted Image (c) Shadow Processed Image

3.0 Structural Feature Extraction:

Roads, buildings and bridges are the main structural features to be extracted from a satellite image. The extraction of these feature are useful for cartographic mapping and updating the geographic information system (GIS) databases. Availability of very high resolution panchromatic images from IKONOS, SPOT and Quickbird sensors opens the possibility of algorithms based on intensity level processing. But though the resolution is poor, multispectral images from other sensors can be used to mask the unwanted spectral components, so that the feature extraction process at intensity level will be much easier. The procedure can be generalized as follows:

Convert spectral radiance to temperature using Landsat ETM+ (Landsat Enhanced Thematic Mapper Plus) images of the region so that we will get an idea of different regions and is able to mask the unwanted regions [10].

Mask the vegetation areas using NDVI (Normalized Differential Vegetation Index) using Multispec32 software. High index values indicate vegetation regions whereas low values represent manmade regions. The equation is given below:

$$NDVI = \frac{NIR - R}{NIR + R} \qquad (1)$$

Mask the water areas using NDWI (Normalized Differential Water Index) Multispec32 software. This step is important for bridge detection problems. The equation is given below:

$$NDWI = \frac{G - NIR}{G + NIR} \qquad (2)$$

If the region has thin clouds which obstruct the feature extraction process, eliminate the effect using intensity level processing.

If the region has denser clouds and the region is near to poles or mountain areas, eliminate the effect using spectral domain processing.

If the region is affected by shadows remove it.

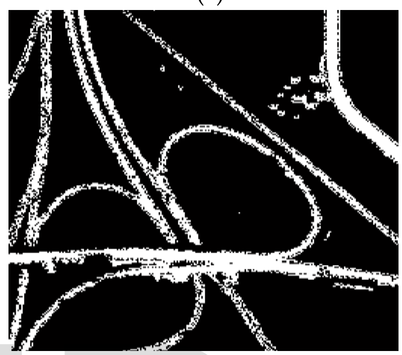
Now the region of interest will be very clear and the structural feature extraction will be much easier.

3.1 Extraction of Roads

Our road extraction method is based on the work described in [2]. In this algorithm a fuzzy inference system is used for detecting the roads. The use of Hough transform to detect lines and gray scale intensity properties of the road are used for developing rules for the fuzzy system. The result obtained for a high curvature road is given in Fig. 6. The same technique can be used for a neural network or genetic algorithm based classifier [11].

Before giving the inputs to these classifiers, masking the vegetation and water regions will give better results as the intensity properties of water and road segment will be similar. But, for this we require multispectral images of the same region. Using Landsat images and converting spectral radiance to temperature, the same region can be classified into different segments. If the inference is given as another input to a neural network classifier, the result is improved further.

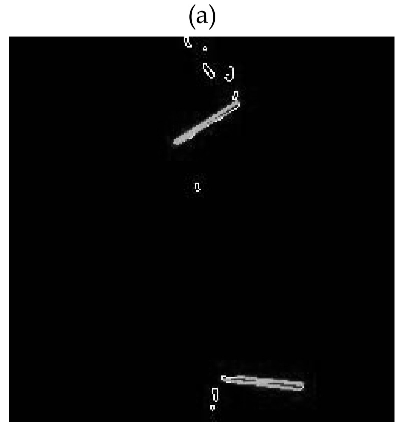
(a)



(b)

Fig. 6: (a) Satellite Image with High Curvature Roads (b) Road Extraction Result

(a)



(b)

Fig. 7: (a) IKONOS Satellite Image (b) Extracted Bridge Regions

3.2 Extraction of bridges

Our bridge extraction method based on fuzzy thresholding is described in [4]. As the algorithm is carefully formulated without considering the geometric features, this can be applied for any type of bridges irrespective of their inclination angle, shape and size. Some of the results using the same algorithm are shown in Fig. 7 and 8 respectively. As the algorithm uses fuzzy thresholding, the parameters required for thresholding is automatically fixed depending on the intensity properties and no user interface is required for the accurate detection of bridges.

(a)

(b)

(c)

(d)

(e)

Fig. 8: (a) IKONOS Image (1-m) (b) Quickbird Image (60-cm) (c) SPOT5 Image (2.5-m) (d) SPOT5 Image (4-m) (e) SPOT5 Image (2.5-m)

3.3 Extraction of Buildings

Our method of building extraction using neural network is described in [12]. Extracting buildings is one of the most complex and challenging tasks as there exist a lot of inhomogeneity due to varying hierarchy. The variety of the type of buildings and also the shapes of rooftops are very inconstant. Also in some areas, the buildings are placed irregularly or too close to each other. For these reasons, even by using high resolution satellite imagery, the quality percentage of building extraction is very less.

Therefore, if building is the structural feature to be extracted, it is better to consider the areas other than the region of interest and to develop a multistep algorithm which eliminates regions out of interest. This method is developed in [3]. Viewing the results in Fig. 10 for the Quickbird image shown in Fig. 9, we can see the detection percentage is increased. Masking vegetation, water, cloud and shadow regions is very important for the case of building extraction.

International Journal of Scientific & Engineering Research, Volume 4, Issue 12, December-2013
ISSN 2229-5518

Fig. 9. Panchromatic Quickbird Satellite Image

(a)

(b)

Fig. 10: (a) Extracted buildings using Neural Networks
(b) Extracted Buildings by Masking Regions out of Interest

4.0 Conclusions:

In this paper, a generalized procedure is formulated for the extraction of structural features from satellite images. Based on this different algorithms are developed for the extraction of roads, bridges and buildings. Elimination of clouds and shadows which supports the structural feature extraction is also discussed. The method tried to combine both spatial and spectral domain to get competitive results. Considering the results, acceptable accuracy for the extracted features is obtained. Future work will focus on the availability of hyperspectral data and to extract maximum information from the hyperspectral data which simplifies the extraction of structural features from satellite images.

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