DTM GENERATION AND FEATURE EXTRACTION FROM SATELLITE IMAGES OF HILLY TERRAINS USING WAVELETS AND WATERSHEDS

K. Parvathi[1], B. S. Prakasa Rao[2], T. Venkateswara Rao[2]

[1]Department of Electronics and Communication Engineering, JITM, Orissa
[2]Department of Geo-Engineering, Centre for Remote Sensing & Information Systems, College of Engineering, Andhra University, Visakhapatnam

Corresponding Author's E-mail: parvathi kodimela@yahoo.com

Abstract— Most of the research in remote sensing is focused on developing well-defined and reliable automated process for the extraction of information from different types of imagery. In this communication we are dealing with the extraction of linear man-made objects (especially buildings) in hilly areas. The analysis of Digital Surface Models (DSM) from hilly terrain data is still challenging especially for highly sloped landscapes. Commonly, the first task to investigate Satellite data is to separate ground and object points as a preparatory step for further object classification aiming at the generation of Digital Terrain Model (DTM). In this paper, object and ground separation in Hilly Terrain (Pan Image of IRS-1C satellite) is addressed by employing Wavelets. Then the Extraction of desired objects (buildings) is done by employing the Marker controlled Watershed Segmentation. Experimental results demonstrate the method effective.

1 INTRODUCTION

Building extraction is a favorite topic of researchers in remote sensing applications. Most of them are based on aerial photographs or Satellite images. Many algorithms have been developed for building extraction from Arial imagery, largely as a result of several research projects that have been sponsored by granting agencies. Examples of these projects are RADIUS project, the MURI project and AMOBE. Number of techniques has been developed based on LIDAR data (Weidner and Farstner 1995). However there are many unsolved problems left. Only a few Authors have addressed the problem of Hilly Terrain. Weidner and Forstner (1995) separated ground and object points in estimating a normalized Digital surface model by subtracting a morphologically filtered DTM from the original DSM. Mass and Vosselman (1995) modeled buildings from LIDAR data in a less sloped area. For hilly terrain, Mass (1999) suggested to apply a filter bank to the interpolated data Vosselman's slope based algorithm (Vosselman 2000) employed morphological filtering and has been further improved by Sitholes adaptive terrain algorithm (Sithole and Vosselman 2003). Cobby (2002), Cobby *et al*. (2001, 2002) segmented rural area from a LIDAR point cloud and classified vegetation. The authors first separated the slightly hilly terrain from the objects using detrending (Daveport *et al*. 2000) to obtain a bilinear interpolated DTM for a hydraulic flood model (Coby 2002).

Wavelets have been used successfully in the development of the lossless image compression standard JPEG 2000 (Gonzalez and Woods 2002), the fingerprint database of the United states FBI (Ogden 1997) denoising signals (Missiti 2000) and the detection of singularities (Mallat 1989). A wavelet approach to separate ground and object points was proposed by Vu *et al* (2002). *K*-means were employed on height to assign pixels to buildings, boundaries, and two types of trees. Further multi resolution algorithm was demonstrated (Vu *et al* 2001, 2003, 2004) which, compared succeeding median filtered resolutions of images to detect boundaries. The approximation of wavelet decomposition and the actual height were used as features for segmentation. Bartels *et al* (2005) proposed a noise robust texture based segmentation approach for hilly data using wavelet packets, co-occurrence matrices and normalized modified histogram thresholding.

In this paper, the separation of ground and object points in hilly terrain using wavelets is addressed. The LIDAR community defines the top layer soil, thin man made layering such as asphalt as bare earth, appearing as ground points [Goswami and Chan 1999). We adopted the same concept for our satellite images, and grass is also considered as bare earth too. Object points comprise detached objects (buildings, trees and bushes) and attached objects (bridges and ramps) (Sithole 2001). The detached objects (buildings, houses) were extracted by applying the Marker controlled Watershed Segmentation on image, which was preprocessed through wavelets.

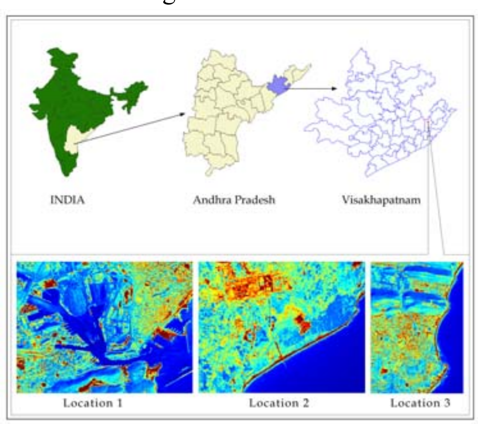

Figure 1 : Location Map of the Study Area

2. SEGMENTATION:

2.1 Background:

In order to partition Satellite data into objects and ground, setting a global height threshold (Homogeneous image) is not always feasible. Houses could reside in valleys or on hills, while inland waters could be located on higher levels (plateau) too as discussed in (Bartles *et al.* 2005). The problem is that there are not only local differences in elevation (eg. Fields to scrub land or streets to houses) but also global altitude differences (eg. Valleys to hills). In order to remove the undesired global slope, wavelets are applied to separate global and local gradients of height. This effect achieved by examining the image at multiple resolutions as worked out by Mallat's algorithm (Mallat 1989). When applied to Satellite data, wavelets separate low and high frequencies i.e., hilly and objects.

2.2 Wavelet transform:

The wavelet transform is mathematical tool that can be used to describe images in multiple resolutions. The wavelet transform can be represented with an equation like Fourier transform.

$$F(w) = \int_{\infty}^{\infty} f(t) e^{jwt} dt \qquad (2.1)$$

$$C(Scale, Position) = \int_{\infty}^{\infty} s(t)\psi(Scale, Position, t)dt \qquad (2.2)$$

The results of wavelet transform are many wavelet coefficients C, which are functions of scale and Position. $\psi(scale, position, t)$ is the wavelet function. If we choose scales and positions based on powers of two (so called dyadic scales and positions) then our analysis will be much more efficient and just as accurate. We obtain such an analysis from the Discrete Wavelet Transform (DWT). For many Images, the low frequency content is the most important part. It is what gives the image identity. The high frequency content imparts flavor or nuance.

In the present study Pan Image of IRS-1C satellite is considered. Fig.1. The image shows the coastal features of Visakhapatnam city in India. According to Mallat's pyramidal algorithm (Mallat 1989), the original image is convolved with low-pass and High-Pass filters associated with a mother wavelet, and down sampled afterwards as shown in figure (3). Four images (each one with half size of the original image) are produced, corresponding to low frequencies in Horizontal and high frequencies in the in the vertical direction (LH), called the horizontal coefficients (cH_1) of original image as shown in figure (2b). The high frequencies in Horizontal and low frequencies in the in the vertical direction (HL), called vertical coefficients (cV_1) as shown in figure (2c). High frequencies in both the directions (HH), called diagonal coefficients (cD_1), and low frequencies in both the directions (LL), called low pass version of the original Image and is the Approximation image (cA_1) of the original Image as shown in figure 2 d & 2a respectively).

$$S = cA_1 + \{cH_1 + cV_1 + cD_1\} \quad \text{----- (2.3)}$$

And iterating the process to J levels.

$$S = cA_J + \sum_{i=1}^{J} \{cH_i + cV_i + cD_i\} \quad \text{-------- (2.4)}$$

Since the Analysis process is iterative in theory, it can be continued indefinitely. In reality the decomposition can be proceeding only until the individual details consist of a single sample or pixel. The

Approximations are related to one another by

$$cA_{J-1} = cA_J + (cH_J + cV_J + cD_J) \quad \text{-------- (2.5)}$$

The quality (in energy) of the Approximation of S by cA_J is

$$qual_J = \frac{|cA_J|^2}{|S|^2} \quad \text{---------- (2.6)}$$

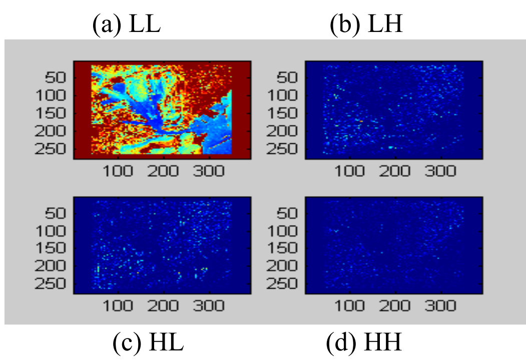

Figure 2: Single level decomposition of Image DWT.

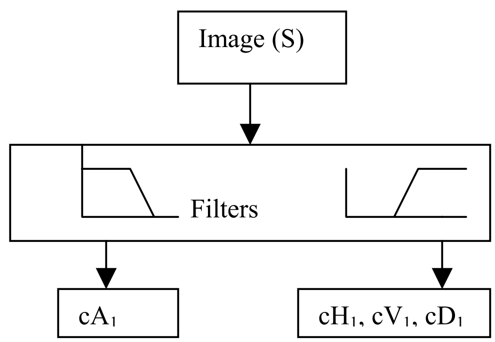

Figure 3:Flow chart level using Decomposition .

In this research, a simple Haar transform is used. The Haar basis is a discrete wavelet transform. The image decomposed using the discrete wavelet transform (DWT) (Luc Vincent and Soille 1991, Luc Vincent 1993) into sub images as shown in Figure 2. The energy is evenly distributed among subimages and therefore the amplitudes of subimages become lower (Bartles *et al*. 2005). Furthermore, by analyzing the subimages energy and entropy of wavelets (2.6), it can be shown that decomposition is meaningful upto level 2.

In this study we applied only level1 decomposition to the data. Discontinuities give responses in the details depending on their relative position to the wavelet kernel. Therefore, the Details cH, cV and cD are evenly treated to achieve a relation invariant representation of discontinuities. As low frequencies represent hills and flat area, cA is replaced with zero value. Three subsets are created form the original Pan image of IRS-1C satellite data. Figure (4a) is a subset of Pan Image. It shows the part of harbor and its surroundings along with seacoast. The synthesis using all the detail coefficients by employing the inverse DWT (Goswami and Chan 1999), deliberately accepting a loss of energy gives Digital Terrain model as shown Figure (4b). The inverse DWT is given

$$S(t) = \sum_{j \in J} \sum_{k \in J} C(j,k) \psi_{j,k}(t) \quad \text{----------- (2.7)}$$

where S(t) is the Original Image , j, k --- Scale ,Position.
C (j, k)------- Coefficients function and
Ψ(t) --------- wavelet function as used in DWT..

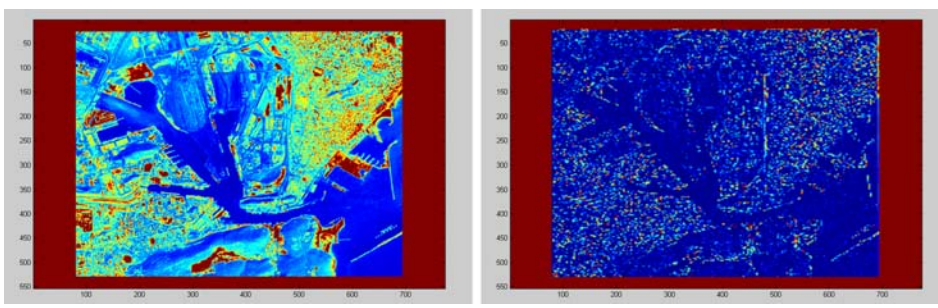

Figure 4:(a) original image (773X 553 X3) (b) Synthesized image using Detail coefficients.

First, hilly terrain could be successfully separated from the objects. Secondly discontinuities typical for man made structures (eg buildings, dams etc.) could be detected. In this paper we considered the Approximation coefficients with respect to the desired objects for image reconstruction instead of making it to zero. Figure (5a) shows the objects of maximum height in red color. These objects are elevated jetties, shipping berths and buildings. Figure (5b) shows the medium elevated objects; buildings, road dividers, roads etc. Figure (5c) shows the buildings in orange and yellow color (less height).

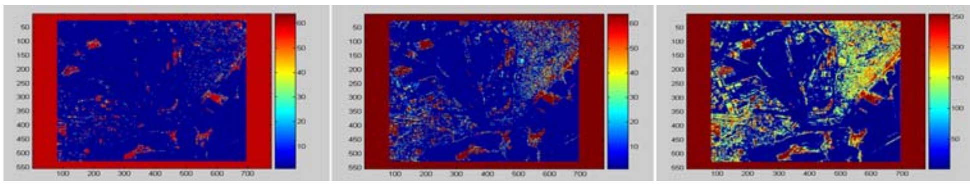

Fig: 5 (a) Synthesized image (b) Synthesized image (c) Synthesized image With cA_1= 2385 with cA_1= 2435 with cA_1= 2485

2.3. EXPERIMENTAL RESULTS

All the computation involving wavelet transform implemented using MATLAB 7.01. Application of the wavelet transform takes very less time, this quick response is mainly due to the property of wavelet decomposition and Reconstruction are fast algorithms. The algorithms are based on convolutions with a bank of filters.

The Fig (6a) is a part of Pan Image (black and white sensor) of IRS-1C. It is a part of Visakhaptanam coast near National Thermal Power Plant area. In the second image of Fig (6a), high raised industry buildings after applying the algorithm. Fig (6b) is also a Pan image of IRS-1C satellite. It is Visakhapatnam seacoast with hills extending into the sea in the north of the image followed by dense city with concrete structures. After applying the above algorithm, hills are obscured and buildings and coastline are highlighted.

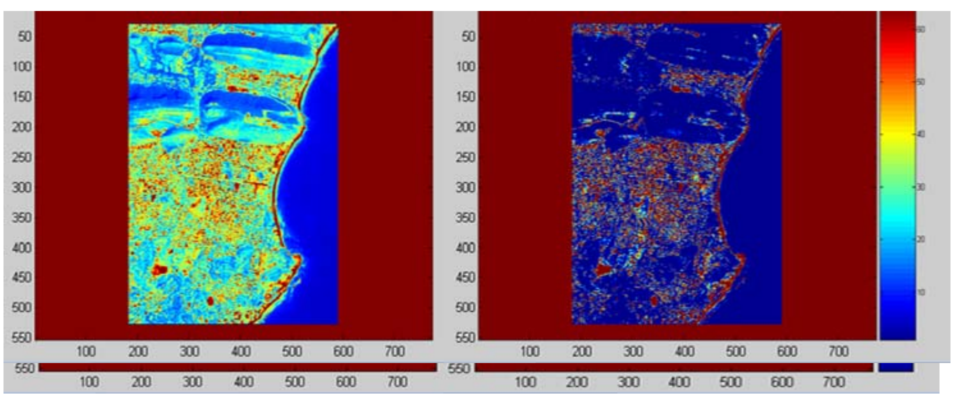

Fig: 6 (a) original image & objects with maximum height extracted. (b) original image & objects extracted.

The challenging task is the segmentation of objects located; there are various attached and detached man-made objects such as industrial and residential buildings, sheds, streets, bridges, and railways, and vegetation such as trees, grass, fields and bushes. In this paper we used a simple Marker controlled Watershed algorithm using mathematical morphology to extract the man made buildings.

3. FEATURE EXTRACTION USING MARKER-CONTROLLED WATERSHED SEGMENTATION:

3.1 Creating markers

The marker-controlled watershed segmentation has been shown to be a robust and flexible method for segmentation of objects with closed contours where the boundaries are expressed as ridges. The marker image used for watershed segmentation is a binary image consisting of either single marker points or larger marker regions where each connected marker is placed inside an object of interest.

Each initial marker has a one-to-one relationship to a specific watershed region, thus the number of markers will equal the final number of watershed regions. After segmentation, the boundaries of the watershed regions are arranged on the desired ridges, thus separating each object from its neighbors. The markers can be manually or automatically selected, but high throughput experiments often employ automatically generated markers to save human time and resources.

3.2 Morphological image reconstruction:

Dilation based Gray scale Image reconstruction: Let I, J be two images defined on the same domain and J$\leq$ I. The reconstruction of I from J, denoted as $\gamma_I^{(rec)}(J)$**,** is obtained by iterating elementary geodesic dilations of J under I until stability is reached.

$$\gamma_I^{(rec)}(J) = \bigcup_{n\geq 1} \delta_I^{(n)}(J) \qquad \text{----------------- (3.1)}$$

where $\delta_I^{(n)}(J)$ can be obtained by iterating n elementary geodesic dilation and the geParvati Kodimelaodesic dilation is

$$\delta_I^1(J) = (J \oplus B) \bigcap I \qquad \text{---------------- (3.2)}$$

(B is the flat structuring element of size I and ∩stands for point wise minimum)

Erosion based Gray scale Reconstruction: Let I, J be two grayscale Images defined on the same domain and J$\leq$ I. The reconstruction of I from J, denoted as $\varphi_I^{(rec)}(J)$, is obtained by iterating elementary geodesic erosions of J above I until stability is reached.

$$\phi_I^{(rec)}(J) = \bigcap_{n\geq 1} \varepsilon_I^n(J) \qquad \text{--------------- (3.3)}$$

where $\varepsilon_I^{(rec)}(J)$ can be obtained by iterating n elementary geodesic Dilation and the geodesic Dilation is

$$\varepsilon_I^1(J) = (J \Theta B) \cup I \qquad \text{---------------- (3.4)}$$

(B is flat structuring element of size I and $\cup$ stands for point wise maximum.)

In this paper we used simple algorithm to create foreground and background markers using Morphological image reconstructions. We used Erosion based Gray scale Reconstruction (3.3),(3.4) followed Dilation based Gray scale Reconstruction (3.1),(3.2) to trace the foreground objects. (Selecting structuring element as per the desired objects). Calculating the Regional maxima of these reconstructed images to get smooth edge foreground objects. Then we superimposed these markers on the original Images. We created the background markers by calculating the Euclean distance of binary version of above superimposed image. Then the Gradient image is modified by morphological reconstruction with foreground and background markers. Application of Watershed Transform gives final segmented images of desired objects. The final results are shown in Fig 6.

ALGORITHM:

Read the color or gray scale image apply wavelet transform.

Reconstruct the image using the required Approximation coefficients(desired objects) and all the detail Coefficients.

Read the Reconstructed image and convert to grayscale.

Make gradient image using appropriate edge detection function.

Mark the foreground objects using morphological reconstruction
(Better than the opening image with a closing)

Calculating the regional maxima, minima to obtain the good forward Markers

Superimpose the foreground marker image on the original image.

Clean the edges of the markers using edge reconstruction.

Compute the background markers.

Compute the Watershed transform of the function**.**

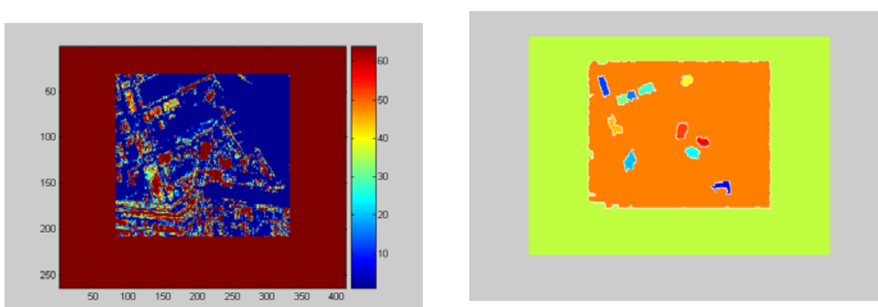

Fig: 7(a) Part of the synthesized image (b) Segmented image showing the man-made of fig 5(c) structures.

EXPERIMENTAL RESULTS:

We used a part of the Pan data of IRS-1C Satellite image which was discussed above. Fig (7a) shows the extracted industrial buildings, roads etc in a part of harbor area, taken form Fig (5c). These extracted objects (with maximum height) from the image. Fig (7b) is the result of segmented algorithm as mentioned above, where industry buildings and harbor berths are extracted.

4. CONCLUSIONS AND FUTURE WORK:

In this Paper, an object feature extractor in challenging hilly DSMs desired from Satellite images has been presented to support further terrain feature classification. However as expected, large flat roofs and attached objects such as bridges excluded. Using additional features complete classification can be done in future investigation.

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