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An Efficient Method For Road Extraction For Urban Planning

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Abstract:

The uses of road map in daily activities are numerous but it is a hassle to construct and update a road map whenever there are changes. research on Automatic Road Extraction (ARE) was explored to solve the difficulties in updating road map. The research started with using Satellite Image (SI), or in short, the ARE-SI project. A Hybrid Simple Colour Space Segmentation and Edge Detection (Hybrid SCSS-EDGE) algorithm was developed to extract roads automatically from satellite-taken images. The extracted road regions are validated by using a segmentation method. These results are valuable for building road map and detecting the changes of the existing road database. The proposed Hybrid Simple Colour Space Segmentation and Edge Detection (Hybrid SCSS-EDGE) algorithm can perform the tasks fully automatic, where the user only needs to input a high-resolution satellite image and wait for the result. Moreover, this system can work on complex road network and generate the extraction result in seconds.

1. Introduction to image processing:

Image Processing is a technique to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-today life for various applications

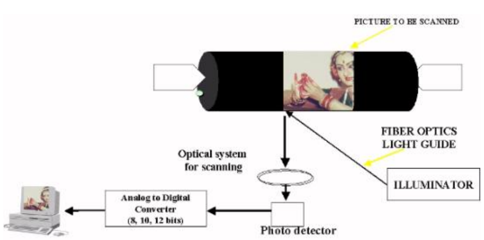

Fig1.1:The schematic diagram of image scanner-digitizer diagram

Methods of Image Processing

There are two methods available in Image Processing.

Analog Image Processing

Analog Image Processing refers to the alteration of image through electrical means. The most common example is the television image.

Digital Image Processing

Digital computers are used to process the image. The image will be converted to digital form using a scanner – digitizer (as shown in Figure 1) and then process it.
The various Image Processing techniques are:

- Image representation
- Image preprocessing
- Image enhancement
- Image restoration
- Image analysis
- Image reconstruction
- Image data compression

1.1 Image Representation:

An image defined in the "real world" is considered to be a function of two real variables, for example, f(x,y) with f as the amplitude (e.g. brightness) of the image at the real coordinate position (x,y).

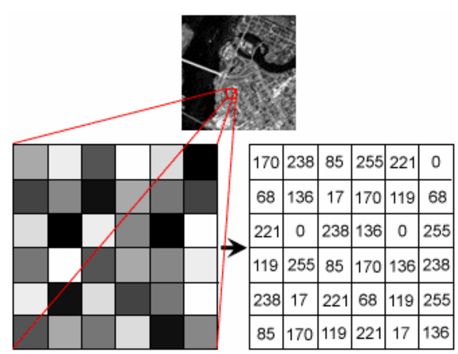

Fig 1.2: Image Representation

The2D continuous image f(x,y) is divided into N rows and M columns. In fact, in most cases f(x,y)--which we might consider to be the physical signal that impinges on the face of a sensor. Typically an image file such as BMP, JPEG, TIFF etc., has some header and information which usually includes details like format identifier (typically first information), resolution, number of bits/pixel, compression type, etc.

1.2 Image Preprocessing

1.2.1 Scaling

The theme of the technique of magnification is to have a closer view by magnifying or zooming the interested part in the imagery. By reduction, we can bring the unmanageable size of data to a manageable limit.

1.2.2 Magnification

This is usually done to improve the scale of display for visual interpretation or sometimes to match the scale of one image to another.

Fig 1.3: Image Magnification

1.2.3 Reduction

To reduce a digital image to the original data, every m^{th} row and m^{th} column of the original imagery is selected and displayed. Another way of accomplishing the same is by taking the average in 'm x m' block and displaying this average after proper rounding of the resultant value.

Fig1.4: Image Reduction

1.2.4 Rotation

Rotation is used in image mosaic, image registration etc. One of the techniques of rotation is 3-pass shear rotation, where rotation matrix can be decomposed into three separable matrices.

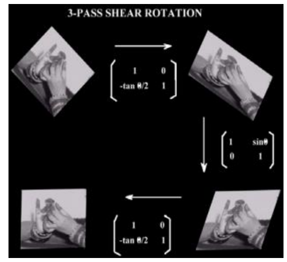

Fig 1.5: Image Rotation

1.2.5 Mosaic

Mosaic is a process of combining two or more images to form a single large image without radiometric imbalance. Mosaic is required to get the synoptic view of the entire area, otherwise capture as small images.

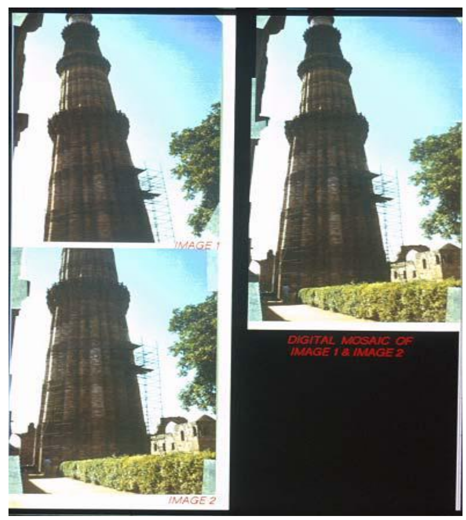

Fig 1.6: Image Mosaicking

1.2 Image Enhancement Techniques

Sometimes image obtained from satellites and conventional and digital cameras lack in contrast and brightness because of the limitations of imaging sub systems and illumination conditions while capturing image. Images may have different types of noise. In image enhancement, the goal is to accentuate certain image features for subsequent analysis or for image display.

2. IMAGE EDGE DETECTION

Introduction

Edges are boundaries between different textures. Edge also can be defined as discontinuities in image intensity from one pixel to another pixel. There are many methods to make edge detection. The most common method for edge detection is to calculate the differentiation of an image. Another method for edge detection uses Hilbert Transform. And we have proposed a new method called short response Hilbert transform (SRHLT) that combines the differentiation method and the Hilbert transform method.

A more accurate algorithm for corner and edge detections that is the improved form of the well-known Harris' algorithm is introduced. First, instead of approximating |*L* [*m*+*x*, *n*+*y*]–*L*[*m*, *n*]|2 just in terms of *x*2, *xy*, and *y*2, we will approximate |*L*[*m*+*x*, *n*+*y*]–*L*[*m*, *n*]|(*L*[*m*+*x*, *n*+*y*]–*L*[*m*, *n*]) by the linear combination of *x*2, *xy*, *y*2, *x*, *y*, and 1. There are 6 bases different from 3 bases.

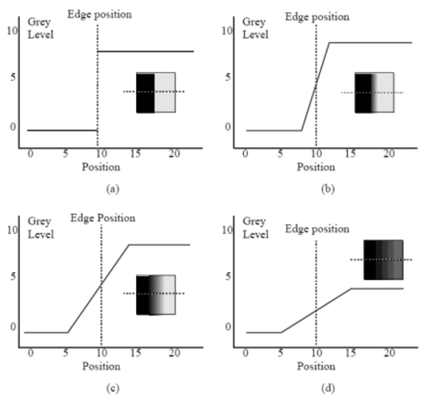

Fig 7: Step edges. (a) The change in level occurs exactly at pixel 10. (b) The same level change as before, but over 4 pixels centered at pixel 10. This is a *ramp* edge. (c) Same level change but over 10 pixels, centered at 10. (d) A smaller change over 10 pixels. The insert shows the way the image would appear, and the dotted line shows where the image was sliced to give the illustrated cross-section.

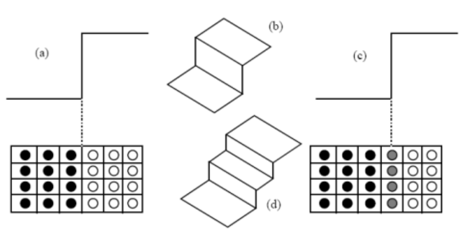

Fig 8: The effect of sampling on a step edge. (a) An ideal step edge. (b) Three dimensional view of the step edge. (c) Step edge sampled at the center of a pixel, instead of on a margin. (d) The result, in three dimensions, has the appearance of a staircase.

2.1. Fist-Order Derivative Edge Detection:

$$\nabla \mathbf{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}. \qquad (0.1)$$

An important quantity in edge detection is the magnitude of this vector, denoted M*f*,

Where $\nabla f = |\nabla \mathbf{f}| = \sqrt{G_x^2 + G_y^2}$. (0.2)

Another important quantity is the direction of the gradient vector. That is,

$$\text{angle of } \nabla \mathbf{f} = \tan^{-1}\left(\frac{G_y}{G_x}\right) \qquad (0.3)$$

Computation of the gradient of an image is based on obtaining the partial derivatives of $\partial f/\partial x$ and $\partial f/\partial y$ at every pixel location. Let the 3×3 area shown in **Fig**. 1.1 represent the gray levels in a neighborhood of an image. One of the simplest ways to implement a first-order partial derivative at point *z*5 is to use the following Roberts Cross-gradient operators:

$$G_x = (z_9 - z_5) \qquad (0.4)$$

and

$$G_y = (z_8 - z_6) \qquad (0.5)$$

These derivatives can be implemented for an entire image by using the masks shown in Fig. 1.2 with the procedure of convolution. Another approach using masks of size 3×3 shown in Fig. 1.3

$$G_x = (z_7 + z_8 + z_9) - (z_1 + z_2 + z_3) \qquad (0.6)$$

and

$$G_y = (z_3 + z_6 + z_9) - (z_1 + z_4 + z_7) \qquad (0.7)$$

a slight variation of these two equations uses a weight of 2 in the center coefficient:

$$G_x = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3) \qquad (0.8)$$

$$G_y = (z_3 + z_6 + z_9) - (z_1 + z_4 + z_7) \qquad (0.9)$$

A weight value of 2 is used to achieve some smoothing by giving more importance to the center point. Fig.1.4, called the Sobel operators, is used to implement these two equations.

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

Fig: 1.1 A 3×3 area of an image.

0	0	0
0	–1	0
0	0	1

0	0	0
0	0	–1
0	1	0

Fig. 1.2 The Roberts operators.

–1	–1	–1
0	0	0
1	1	1

–1	0	1
–1	0	1
–1	0	1

Fig. 1.3The Prewitt operators.

–1	–2	–1
0	0	0
1	2	1

–1	0	1
–2	0	2
–1	0	1

Fig. 1.4 The Sobel operators.

2.2. Second-Order Derivative Edge detection

The Laplacian of a 2-D function $f(x, y)$ is a second-order derivative defined as

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \qquad (1.1)$$

There are two digital approximations to the Laplacian for a 3×3 region:

$$\nabla^2 f = 4z_5 - (z_2 + z_4 + z_6 + z_8) \qquad (1.2)$$

$$\nabla^2 f = 8z_5 - (z_1 + z_2 + z_3 + z_4 + z_6 + z_7 + z_8 + z_9) \qquad (2.3)$$

where the z's are defined in Fig. 2.1. Masks for implementing these two equations are shown in Fig. 2.1.

0	–1	0
–1	4	–1
0	–1	0

(a)

–1	–1	–1
–1	8	–1
–1	–1	–1

(b)

Fig. 2.1 Two kind of 3×3 Laplacian mask.

The Laplacian is usually combined with smoothing as a precursor to finding edges via zero-crossings. The 2-D Gaussian function

$$h(x, y) = -e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (1.3)$$

Where σ is the standard deviation, blurs the image with the degree of blurring being determined by the value of σ. The Laplacian of h is

$$\nabla^2 h(x, y) = -\left[\frac{x^2 + y^2 - 2\sigma^2}{\sigma^4}\right] e^{-\frac{r^2}{2\sigma^2}} \qquad (1.4)$$

This function is commonly referred to as the Laplacian of Gaussian (LOG).

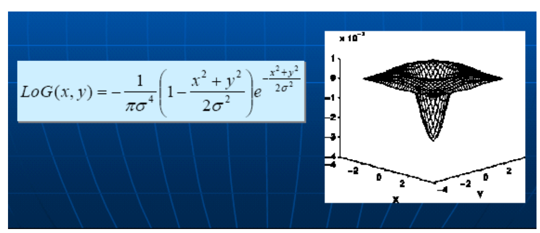

Fig.2.2 dimension coordinates of Laplacian of Gaussian (LOG).

After calculating the two-dimensional second-order derivative of an image, we find the value of a point which is greater than a specified threshold and one of its neighbors is less than the negative of the threshold. The property of this point is called zero-crossing and we can denote it as an edge point. We note two additional properties of the second derivative around an edge: (1) It produces two values for every edge in an image (an undesirable feature); and (2) an imaginary straight line joining the extreme positive and negative values of the second derivative would cross zero near the midpoint of the edge. This zero-crossing property of the second derivative is quite useful for locating the centers of thick edges.

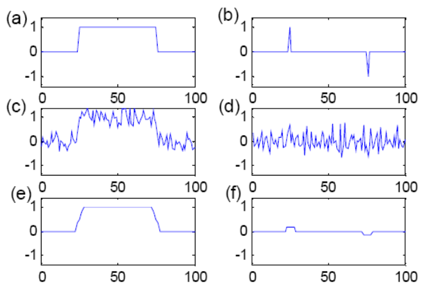

Fig. 2.3 Using differentiation to detect (a) the sharp edges, (c) the step edges with noise, and (e) the ramp edges. (b)(d)(e) are the results of differentiation of (a)(c)(e).

2.3**. Hilbert Transform for Edge Detection**

There is another method for edge detection that uses the Hilbert transform (HLT). The HLT is

$$g_H(\tau) = h(x) * g(x), \quad \text{where} \quad h(x) = \frac{1}{\pi x} \qquad (2.1)$$

and * means convolution. Alternatively,

$$G_H(f) = H(f)G(f) \qquad (2.2)$$

Where $G(f) = FT[g(x)]$ (FT means the Fourier transform), $G_H(f) = FT[g_H(x)]$, and

$$H(f) = -j\,\mathrm{sgn}(f), \qquad (2.3)$$

Where the sign function is defined as

$$\begin{aligned} &\mathrm{sgn}(f) = 1 \text{ when } f > 0, \\ &\mathrm{sgn}(f) = -1 \text{ when } f < 0, \\ &\mathrm{sgn}(0) = 0 \end{aligned} \qquad (2.4)$$

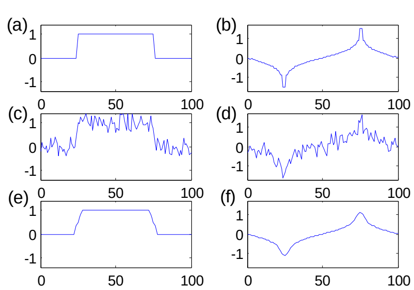

Fig. 3.1 Using HLTs to detect (a) the sharp edges, (c) the step edges with noise, and (e) the ramp edges. (b)(d)(e) Are the results of the HLTs of (a)(c)(e)

2.4. Short Response Hilbert Transform for Edge Detection

Based on Canny's criterion, we develop the short response Hilbert transform (SRHLT), which is the intermediate of the original HLT and the differentiation operation. We also find that there are many ways to define the SRHLT.

2.5. Improved Harri's Algorithm for Corner and Edge Detections

First, they used a quadratic polynomial to approximate the variation around [*m*, *n*]:

$$\begin{aligned} &\left|L[m+x, n+y] - L[m,n]\right|^2 \\ &= A_{m,n}x^2 + 2C_{m,n}xy + B_{m,n}y^2 + \text{remained terms}, \end{aligned} \qquad (3.1)$$

Where *Am ,n*, *Bm*, *n*, and *Cm*, *n* were calculated from the correlations between the variations and a window function:

$$\begin{aligned} &A_{m,n} = X^2 \otimes w, \quad B_{m,n} = Y^2 \otimes w, \quad C_{m,n} = XY \otimes w, \\ &X = L[m,n] \otimes [-1,0,1], \quad Y = L[m,n] \otimes [-1,0,1]^T, \\ &w_{x,y} = \exp[-(x^2+y^2)/2\sigma^2]. \end{aligned} \qquad (3.2)$$

Then the variations along the principal axes can be calculated from the eigen values of the following 2x2 matrix:

$$\mathrm{H}_{m,n} = \begin{bmatrix} A_{m,n} & C_{m,n} \\ C_{m,n} & B_{m,n} \end{bmatrix}. \qquad (3.3)$$

Algorithm

2.6. Fist-Order Derivative Edge Detection

An important quantity in edge detection is the magnitude of this vector, denoted ∇f, where

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−1	−1	−1
−1	8	−1
−1	−1	−1

$$\nabla \mathbf{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \quad (4.1)$$

The magnitude gives the maximum rate of increase of $f(x, y)$ per unit distance in the direction of $\nabla \mathbf{f}$.

$$\nabla f = |\nabla \mathbf{f}| = \sqrt{G_x^2 + G_y^2} \quad (4.2)$$

Another important quantity is the direction of the gradient vector. That is,

$$\text{angle of } \nabla \mathbf{f} = \tan^{-1}\left(\frac{G_y}{G_x}\right) \quad (4.3)$$

where the angle is measured with respect to the x-axis. The direction of an edge at (x, y) is perpendicular to the direction of the gradient vector at that point. Computation of the gradient of an image is based on obtaining the partial derivatives of $\partial f / \partial x$ and $\partial f / \partial y$ at every pixel location.

2.7. Second-Order Derivative Edge Detection

The Laplacian of a 2-D function $f(x, y)$ is a second-order derivative defined as

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \quad (5.1)$$

There are two digital approximations to the Laplacian for a 3×3 region:

$$\nabla^2 f = 4z_5 - (z_2 + z_4 + z_6 + z_8) \quad (5.2)$$

$$\nabla^2 f = 8z_5 - (z_1 + z_2 + z_3 + z_4 + z_6 + z_7 + z_8 + z_9) \quad (5.3)$$

where the z's are defined in **Fig** 1.1 . Masks for implementing these two equations are shown in **Fig**.7.1

0	−1	0
−1	4	−1
0	−1	0

(a)

−1	−1	−1
−1	8	−1
−1	−1	−1

(b)

Fig: 7.1Two kind of 3×3 Laplacian mask.

The Laplacian is usually combined with smoothing as a precursor to finding edges via zero-crossings. The 2-D Gaussian function

$$h(x, y) = -e^{-\frac{x^2+y^2}{2\sigma^2}}, \quad (5.4)$$

Where σ is the standard deviation, blurs the image with the degree of blurring being determined by the value of σ. The Laplacian of h is

$$\nabla^2 h(x, y) = -\left[\frac{x^2 + y^2 - 2\sigma^2}{\sigma^4}\right] e^{-\frac{r^2}{2\sigma^2}}. \quad (5.5)$$

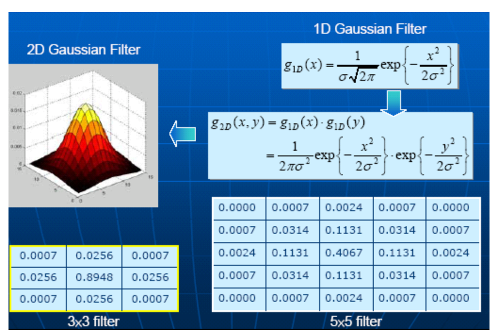


Fig.7.2 An 11×11 mask approximation to Laplacian of Gaussian (LOG).

2.8. Hilbert Transform for Edge Detection

There is another method for edge detection that uses the Hilbert transform (HLT). The HLT is

$$g_H(\tau) = h(x) * g(x), \quad \text{where } h(x) = \frac{1}{\pi x} \quad (6.1)$$

and * means convolution. Alternatively,

$$G_H(f) = H(f)G(f) \tag{6.2}$$

Where $G(f) = FT[g(x)]$ (FT means the Fourier transform), $G_H(f) = FT[g_H(x)]$, and

$$H(f) = -j\,\mathrm{sgn}(f), \tag{6.3}$$

Where the sign function is defined as

$$\begin{aligned} &\mathrm{sgn}(f) = 1 \text{ when } f > 0, \\ &\mathrm{sgn}(f) = -1 \text{ when } f < 0, \\ &\mathrm{sgn}(0) = 0 \end{aligned} \tag{6.4}$$

2.9. Short Response Hilbert Transform for Edge Detection

Based on Canny's criterion, we develop the short response Hilbert transform (SRHLT), which is the intermediate of the original HLT and the differentiation operation. For edge detection, the SRHLT can compromise the advantages of the HLT and differentiation. It can well distinguish the edges from the non-edge regions and at the same time are robust to noise. We also find that there are many ways to define the SRHLT.

3. IMAGE SEGMENTATION

3.1. Segmentation Method

Segmentation process consists of several steps. The first of all is input image conversion to chosen feature space, which may depends of used clustering method. In our case is input image converted from RGB color space to L*u*v*color space and L*, u* and v* values are features respectively attributes for fuzzyc-means clustering method.

Next step after input image conversion to feature space is applied clustering. In our case, we have chosen fuzzy c-means clustering method, settings are in experiments section.

After these two steps (input image conversion to feature space of clustering method and accomplishing clustering method) is accomplished next segmentation method.

Combination of both Image Segmentation And Edge Detection

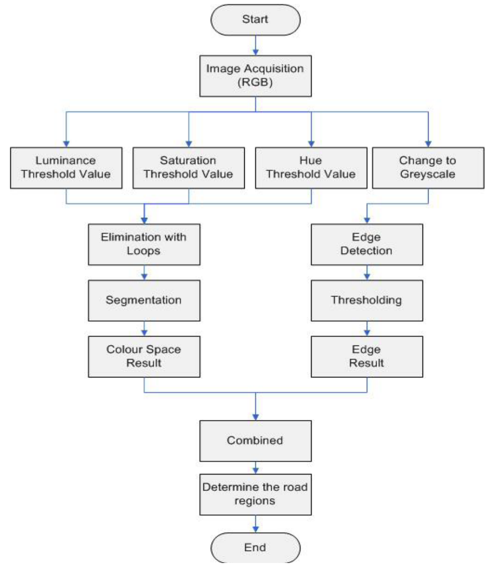


Fig 3.1 Combination of both image segmentation and Edge detection

4. RESULTS

Fig 4.1 Original input image:

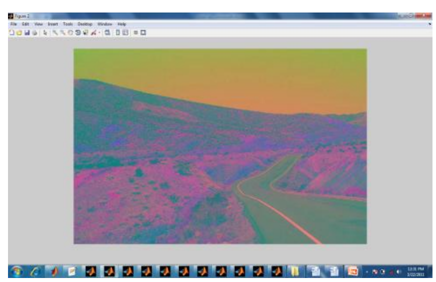


Fig 4.2 HSV image

Fig 4.3 Gray Scaled Image

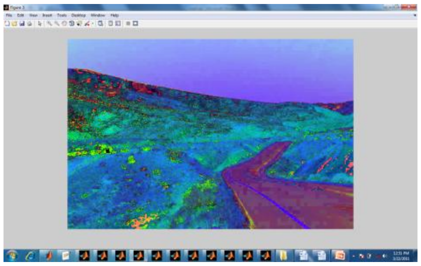


Fig 4.4 YCBCR Image

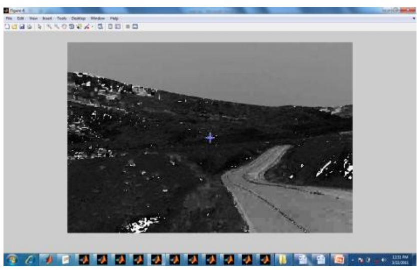


Fig 4.5 IM tool Image

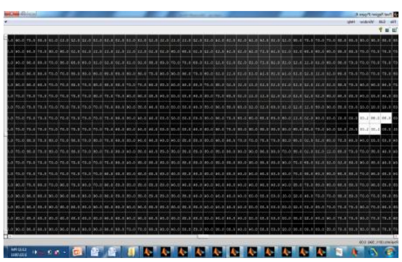
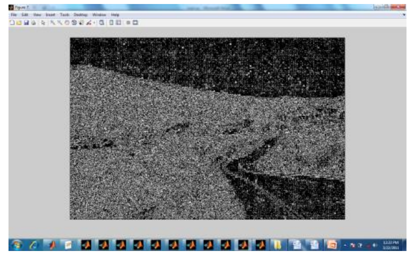
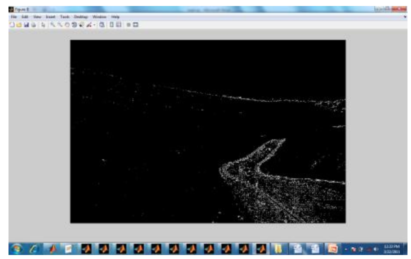


Fig 4.6 Pixel Representations

Fig 4.7 Final Edge Detected Image





5. CONCLUSION

The road extraction process can be divided into two groups, namely automatic and semi- automatic (or manual). The automatic way is getting popular attentions due to its short processing time. The Hybrid SCSS-EDGE methodology mentioned in this study is able to extract road regions automatically, both in rural and urban areas, from high-resolution satellite imageries in a very fast way. The results can be obtained from the hybrid results from color space elements (luminance, saturation and hue) and the edge details of roads. Besides, a number of adjustments are discussed to effectively extract the road network. The advantages of this method are its fast, accurate yet simple algorithms. In addition, it can provide valuable references for organizations or companies which deal with road maps and GPS (Global Position System).

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