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Comparative Study of Satellite Image Edge Detection Techniques

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ABSTRACT: For Analysis of the image the most commonly used technique is Edge detection is one of the most commonly used operations in image analysis. Different techniques have been discussed and compared earlier by researchers. Different edge detection techniques such as Sobel, Prewitt, Robert, Canny, Log, and OSTU have been used. Various examples are found for an application of edge detection technique on normal raster based images. But to detect an edge of object present in geographical data or in satellite images there is need to recognize best edge detection technique. Hence present research work *has* been focused on comparative study and implementation of various existing classic edge detection techniques and proposed Cellular Automata edge detection technique to detect an edge of an object present in satellite imagery data.

KEYWORDS: Satellite imagery data, edge detection techniques, Sobel method, Prewitt method, Roberts, LoG, Canny Operator methods, cellular automata (CA).

I. Introduction

Edge detection is an important area in the field of computer vision. To achieve segmentation and recognition process edges are used. It indicates the boundary between overlapping objects. If edges are identified accurately, all of the objects can be located and the basic properties can be measured i.e shape and size etc. An important and essential tool for image identification and classification in the Computer Vision field is Edge detections. Edge detection is a fundamental of low-level image processing and good edges are necessary for higher level processing [1]. In general edge detectors may face difficulties in different situations. The quality of edge detection is dependent on lighting conditions, the presence of objects of similar intensities, density of edges in the scene, and noise [2]. Various edge detection techniques are used in image segmentation such as Sobel, Prewitt, Robert, Canny, Log, and OSTU and so on. Some of the practical applications of image segmentation are [3]:

1. Medical Imaging: In medical imaging to locate tumors and other pathologies, Measure tissue volume, Computer guided surgery, treatment planning.
2. Locate objects in satellite images (Roads, forest etc.).
3. Face and fingerprint Recognition.
4. Traffic control systems

Image segmentation is normally found in the edge detection process for normal images like pictures or any raster data. But for many spatial problems like land management and planning there is need to deal with geographical data or satellite images and to solve such problem image segmentation plays one of most important role. So on this background there is need to identify appropriate edge detection method for geographical or satellite imagery data.

Hence present research work focuses on comparative study of different edge detection techniques to recognize an object present in the satellite images. Based on this research statement, we have studied and tested different edge detection techniques to detect edges of an object present in satellite images. This satellite imagery data has been procured from various sources like Google image and different satellite sensors. Practical work has been done using Matlab 7 software.

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II. Related work

Among the common edge detection methods, we can refer to the classic edge detection methods such Sobel and Robert edge detection methods in which the maximum local gradients of the image are used as a representative of the image edge detection based on the morphology and the physics. [4, 5]

A. *Sobel method*

The computation of the partial derivation in gradient may be approximated in digital images by using the Sobel operators which are shown in the masks below:

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Figure 1: The Sobel masks

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these Gx and Gy). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient [6]. The gradient magnitude is given by:

Typically, an approximate magnitude is computed using: which is much faster to compute.

$$G=Gx+Gy$$

BW=edge (I, 'sobel') specifies the Sobel method.

BW = edge (I, 'sobel', thresh) specifies the sensitivity threshold for the Sobel method. Edge ignores all edges that are not stronger than thresh. If you do not specify thresh, or if thresh is empty, edge chooses the value automatically. The main disadvantage of these edge detectors is their dependence on the size of the object; they are having high sensitivity to noise, and are inaccurate.

B. *Roberts method*

The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point [7].

The operator consists of a pair of 2×2 convolution kernels as shown in Figure. One kernel is simply the other rotated by 90°. This is very similar to the Sobel operator.

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Figure 2: The Roberts masks

These kernels are designed to respond maximally to edges running at 45° to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. Approximately magnitude is computed using: This is much faster to compute magnitude.

$$|G| = |Gx| + |Gy|$$

BW = edge (I,'roberts') specifies the Roberts method.

BW = edge (I,'roberts',thresh) specifies the sensitivity threshold for the Roberts method.

Edge ignores all edges that are not stronger than thresh. If you do not specify thresh, or if thresh is empty, edge chooses the value automatically.

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*C. **Prewitt method***

The Prewitt operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations [7]. On the other hand, the gradient approximation which it produces is relatively crude, in particular for high frequency variations in the image.

Mathematically, the operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives - one for horizontal changes, and one for vertical. If we define A as the source image, and GX and GY are two images which at each point contain the horizontal and vertical derivative approximations, the latter are computed as:

$$\mathbf{G_x} = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} * \mathbf{A} \quad \text{and} \quad \mathbf{G_y} = \begin{bmatrix} +1 & +1 & +1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} * \mathbf{A}$$

Figure 3: The Prewitt masks

Where * here denotes the 2 dimensional convolution operation.

Since the Prewitt kernels can be decomposed as the products of an averaging and a differentiation kernel, they compute the gradient with smoothing. For example, G_X can be written as

$$\begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 1 \end{bmatrix}$$

The *x*-coordinate is defined here as increasing in the "right"-direction, and the *y*-coordinate is defined as increasing in the "down"-direction.

BW = edge (I,'prewitt') specifies the Prewitt method.

BW = edge (I,'prewitt',thresh) specifies the sensitivity threshold for the Prewitt method.

Edge ignores all edges that are not stronger than thresh. If you do not specify thresh, or if thresh is empty, edge chooses the value automatically.

*D. **Laplacian of Gaussian method***

This is a compound operator that combines a smoothing operation, using a Gaussian-shaped, linear phase FIR filter, with a differentiation operation, using a discrete Laplacian [9]. The edges are identified by the location of zero crossings (recall that the second derivative changes sign in the vicinity of maxima of the first derivative). As Laplace operator may detect edges as well as noise (isolated, out-of-range), it may be desirable to smooth the image first by convolution with a Gaussian kernel of width σ

$$G_\sigma(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} exp[-\frac{x^2+y^2}{2\sigma^2}]$$

We have LoG as an operator or convolution kernel defined as

$$LoG \triangleq \triangle G_\sigma(x,y) = \frac{\partial^2}{\partial x^2} G_\sigma(x,y) + \frac{\delta^2}{\partial y^2} G_\sigma(x,y) = \frac{x^2+y^2-2\sigma^2}{\sigma^4} e^{-(x^2+y^2)/2\sigma^2}$$

BW = edge (I,'log') specifies the Laplacian of Gaussian method.

BW = edge (I,'log',thresh) specifies the sensitivity threshold for the Laplacian of Gaussian method. Edge ignores all edges that are not stronger than thresh.

*E. **Canny Method***

The Canny edge detector is widely considered to be the standard edge detection algorithm in the industry. It was first created by John Canny for his Master's thesis at MIT in 1983 [2], and still outperforms many of the newer algorithms that have been developed. Canny saw the edge detection problem as a signal processing optimization problem, so he developed an objective function to be optimized [2]. The solution to this problem was a rather complex exponential function, but Canny found several ways to approximate and optimize the edge-searching problem. The steps in the canny edge detector are as follows:

2.5.1 **Smooth the image with a two dimensional Gaussian**: In most cases the computation of a two dimensional Gaussian is costly, so it is approximated by two one dimensional Gaussians, one in the x direction and the other in the y direction.

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2.5.2 **Take the gradient of the image**: This shows changes in intensity, which indicates the presence of edges. This actually gives two results, the gradient in the x direction and the gradient in the y direction.
2.5.3 **Non-maximal suppression**: Edges will occur at points the where the gradient is at a maximum. Therefore, all points not at a maximum should be suppressed. In order to do this, the magnitude and direction of the gradient is computed at each pixel. Then for each pixel check if the magnitude of the gradient is greater at one pixel's distance away in either the positive or the negative direction perpendicular to the gradient. If the pixel is not greater than both, suppress it.
2.5.4 **Edge Thresholding**: The method of thresholding used by the Canny Edge Detector is referred to as "hysteresis". It makes use of both a high threshold and a low threshold. If a pixel has a value above the high threshold, it is set as an edge pixel. If a pixel has a value above the low threshold and is the neighbour of an edge pixel, it is set as an edge pixel as well. If a pixel has a value above the low threshold but is not the neighbour of an edge pixel, it is not set as an edge pixel. If a pixel has a value below the low threshold, it is never set as an edge pixel.
BW = edge (I,'canny') specifies the Canny method.
BW = edge (I,'canny',thresh) specifies sensitivity thresholds for the Canny method [2].
Here thresh is a two element vector in which the first element is the low threshold, and the second element is the high threshold.

III. PROPOSED EDGE DETECTION METHOD

Many researchers have proved that a cellular automaton is one of the good techniques to use for satellite image detection. [10, 11, 12], and cellular learning automata [13, 14] are also among the very act-used methods of detecting edges. All of these methods need a completely noise-free image to detect edges and they do not yield a satisfactory output for images which are a little noisy.
The main focus of this research is to eliminate noise, to extract the correct and to detect image edges by using the unique features of cellular automata. In this method, for noise elimination and edge detection in an M image a two-dimensional bilinear convolution cellular automaton with M lines and N columns is used. Each pixel of the image is mapped on one cell of the cellular automata, then each cell, depending on its current state and the statues of the their neighbouring cell, and through the execution of predefined rules of Cellular automata, finally decides to which of the more than 10 classes of different land use and land cover (LULC) for the pixel corresponding to the cell it belongs. To determine the state of each pixel, more than 10 different states in the Moor contiguity are defined below.
Von Neumann neighbourhood: In Von Neumann neighbourhood, central cells are influenced by its nearest four neighbourhood cells.

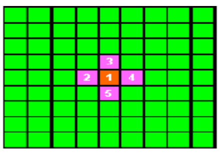

Fig 4: Von Neumann neighbourhood to represent central and neighbouring cells in 2D Cellular automata

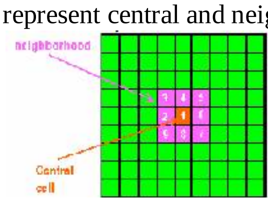

Fig 5: Moor neighbourhood to represent central and neighbouring cells in 2D cellular Automata

As stated above feature extraction is also one of the attractions of this paper, hence, by using image pixel colour notation, we have classified the image for different kinds of LULC classes given below.

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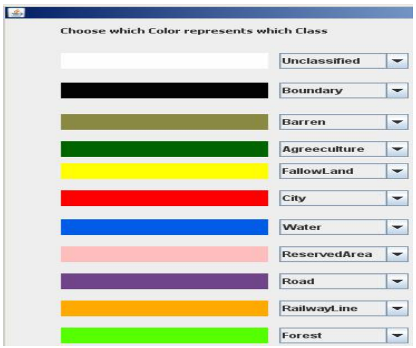

Fig 6: Feature Extraction from Satellite image

To calculate the value of each pixel, we have mapped each coloured pixel with predefined LULC class name as given in below figure. Each class refers to an object in the satellite image.

Fig 7: Coloured Pixel value mapped to LULC class

The main purpose of using proposed cellular automata method is to eliminate noise and detect edge simultaneously. Using cellular automata, the state of black coloured pixel (here state of pixel denotes edge) is decided according to the predefined rules set for Cellular Automata.

IV. RESEARCH METHODOLOGY

1.1. Satellite Image Edge Detection Algorithm used for classic edge detection techniques

Following algorithm has been used to study and implementation of various classic edge detection techniques for satellite images, results and conclusion obtained:

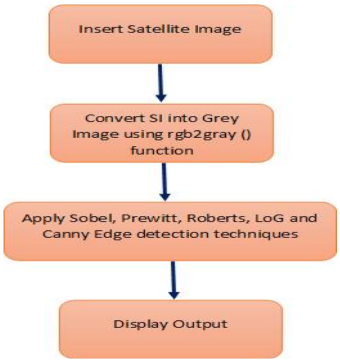

Fig. 8: Algorithm used to implement classic edge detection techniques

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1.2. Cellular Automata

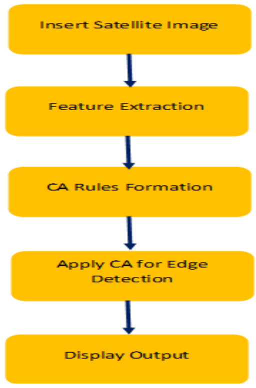

Fig. 9: Algorithm used to implement Cellular Automata edge detection technique

V. RESULT INTERPRETATION AND COMPARISON

Implementation of the techniques was done on satellite images. Coloured, classified image were converted into gray scale image. On the resultant image different edge detection techniques were applied.

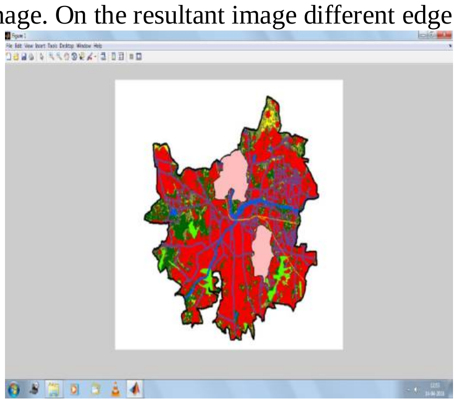

Figure 10: Original Satellite Image

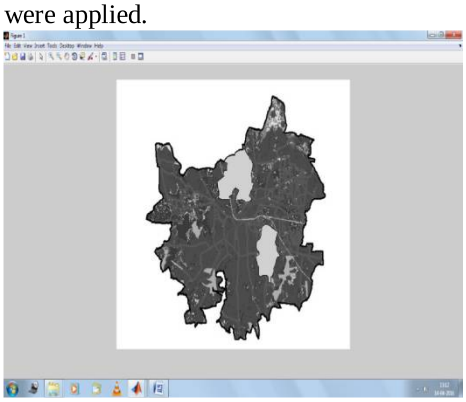

Figure 11: Grey Image

The original satellite image is converted in to grey image using matlab software 7 which is shown in the above figure. The below results shows the edge detected using different operators.

Figure 12: Using Sobel Operator

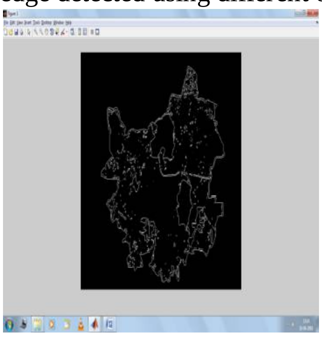

Figure 13: Using Prewitt Operator

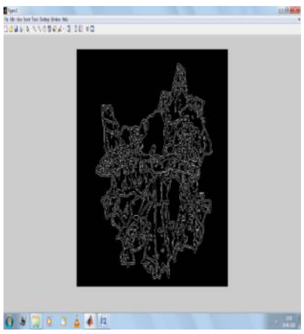

Figure 14: Using LoG Operator

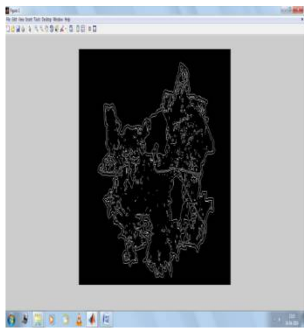

Figure 15: Using Canny Operator

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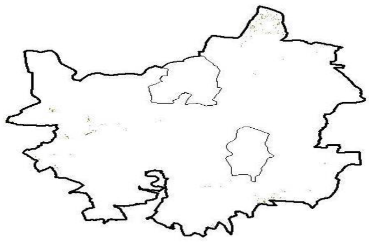

Figure 16: Result of Edge detected image using Cellular Automata (CA)

In this part, our proposed edge detection method is evaluated by comparing it with the Sobel, Robert, Prewitt, Canny and LoG operator edge detection techniques, which are commonly and widely used for edge detection. The results obtained by applying the different edge detection techniques methods and our proposed Cellular Automata for edge detection are shown in above result sections. As can be seen in above figures where we have used different edge detection techniques like the images optioned by using the Robert, Sobel, Prewitt, Canny and LoG operator methods include back ground from the original image and non-edge parts, while these short comings are largely eliminated in our proposed Cellular Automata edge detection method.

VI. CONCLUSION

As edge detection techniques play a vital role in segmentation and object recognition process of analysis of any image, various edge detection techniques like Sobel, Prewitt, Robert, Canny, Log etc. are studied and implemented to detect an edge of object present in satellite imagery data. In our paper, a new method of noise elimination, feature extraction and edge detection of satellite images is presented in which bilinear cellular automata is used. Results have been shown using Robert, Sobel, Canny and LoG operator edge detection techniques are employed for noise elimination and then edge detection is carried out, while in our proposed bilinear cellular automata method noise elimination and edge detection are performed simultaneously. In our method, the state of each pixel (i.e. edge) is decided according to the predefined Cellular Automata rules determined, and the pixel takes on the state decided for it. Experiments carried out in the empirical tests acknowledge the efficiency of our proposed method.

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