Image Segmentation Techniques for Remote Sensing Satellite Images

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Abstract:

The use of satellite imagery has become an integral aspect in the planning of multiple domains that include disaster management and analysis of natural calamity images, snow cover mapping, smart city development, etc. Extraction of urban information like linear features (roads), structured features (buildings, dams, man-made structures), boundaries of water bodies) from satellite images has now become an important area in remote sensing studies.

The whole part of a digital image is not useful for a particular purpose hence the image needs to be segmented. Various methods for image segmentation have been proposed but the choice of a particular method depends upon our requirement. Hence it is necessary to have a basic insight of different methods used for remote sensing satellite images. This paper gives a brief explanation of various segmentation methods and the use of these methods on different data sets.

Keywords: Image Segmentation, Remote Sensing Images, Satellite Images, Filters, Edge Detection.

1. Introduction

A digital image can be partitioned into multiple segments using image segmentation. Segmentation is used to represent an image in a more meaningful way that is easy to analyze. By segments, we mean pixels i.e., similar pixels in a region are grouped to form segments. Various criteria to find the similarity among pixels can be color, intensity, or texture. The Segmentation process is used to find the target region in a particular image. Various techniques of segmentation have been proposed but the selection of technique varies from application to application.
Remote Sensing is the process of detecting and monitoring the physical characteristics of earth surfaces and phenomenon with the use of sensors that is not in physical contact to the surface and phenomena of interest. GIS database can be generated and updated using remotely sensed data in many applications. A large amount of information is contained in remote sensing satellite images and is generally corrupted with many factors like noise. The textural features of remotely sensed images are generally studied by morphological transformations.

A digital image can be defined as a set of pixels. Satellite images are the images of the earth and other planets captured by different Satellites from outer space. Satellite images are generally masked with cloud shadow, hence they are difficult to detect [Fawwaz,2018].

Satellite imagery is used for many applications such as Earth observation, space astronomy, science research, etc. The spatial resolution of the Satellite describes the level of detail. Satellite images like digital photographs are also made up of little dots called pixels. The width of each pixel is the satellite’s spatial resolution. Fig.1 shows the LISS III (Linear Imaging Self Scanning Sensor) JPEG image for the Belgaum region and the spatial resolution of 23.5 m. This image has two regions: Vegetation is denoted by red and yellow while brown color denotes an uncultivated region. Figure 1 (b) is the IKONOS satellite pan image showing building features and Figure (c) shows the water body of the Bhopal city.

Figure 1: (a) LISS III Image [Ashketkar,2013]
Image processing is used to perform some operation over a digital image using computer algorithms to get a magnified image or to retrieve some valuable information. The extraction of useful information by image processing must be done in such a way that it should not affect the other features of an image. Some portion of an image contains information that is not useful for a particular application then to process the whole image is not necessary [Krishnan, 2017]. Hence, the image is divided into multiple segments. The pixels that have similar attributes are grouped using image segmentation [Yin,2018]. By using image segmentation, we can create a pixel-wise mask for each object in an image, this way we can have a clearer understanding of the object in an image [Sharma, 2019].

Image segmentation is used in almost every field of science- Satellite imagery, computer vision, machine vision, biometrics, military, feature extraction, recognition of objects from the given image [Saini,2014]. Image segmentation can be categorized into semantic segmentation, where objects are classified as a single substance and instance segmentation, where each object is identified individually [Sharma, 2019]. The rest of the paper is organized as follows: SectionII focuses on different methods for image segmentation. Section III contains a literature survey and section IV includes a conclusion.
2. Image Segmentation methods:

The image segmentation methods can be categorized into the following types based on two properties of an image [Dass, 2012]:

(a) Detecting Discontinuity: We can partition an image based on abrupt changes in intensity. This includes the algorithm like Edge Detection [Saini, 2014].

(b) Detecting Similarity: We can partition an image into similar regions. This includes algorithms like thresholding, Region growing, merging, and splitting [Naraghi, 2011; Saini, 2014].

Each image has its own type. It is not easy to find a segmentation technique that can be applied to a particular type of image [Saini, 2014]. Since the same method applied to two different images can't always give good results. Hence, image segmentation techniques can be divided into six types as shown in Figure 2.

![Image Segmentation Techniques](Image)

Figure 2: Various image segmentation techniques [Khan, 2013]

An edge can be considered as a boundary between two different regions in an image [Maini, 2009; Katiyar, 2014; Jayakumar, 2014; Dharampal, 2015]. Edge detection is to find sharp discontinuities in an image [Maini, 2009; Katiyar, 2014; Jayakumar, 2014]. Edge detection is particularly used for feature detection and feature extraction [Naraghi, 2011; Dharampal, 2015]. Generally, three basic types of features are extracted: Areal features, Linear features, and point-like features [Xi, 2012]. Edge detection of the noisy image is difficult because both contain high-frequency contents [Maini, 2009]. Hence edge detection algorithms include filtration, enhancement, detection, and localization [Jayakumar, 2014; Krishnan, 2017; N., 2009].
Fuzzy systems are easy to understand as the membership functions can partition the data space properly. A fuzzification function can be used to transform a gray-scale image into a fuzzy image [Khan, 2013]. Fuzzy k-means and Fuzzy C-means (FCM) are widely used methods in image processing. Fuzzy clustering methods divide the input pixel into groups or clusters according to some homogeneity criteria like distance, intensity, and connectivity [Dass, 2012].

An image can also be segmented using a partial differential equation. The active contour model or snake transforms the segmentation problem into the PDE framework. Snakes are computer-generated curves that move over the image to find object boundaries. The drawback of this method is that it requires user interaction. Three most commonly used PDE based methods are: Snakes, Level set, and Mumford Shah model [Dass, 2012; Khan, 2013].

Segmentation using Artificial Neural Network is a fast method thus it is useful for real-time applications [Dass, 2012]. Firstly, an image is mapped into a neural network where each neuron corresponds to a pixel. The neural network is trained by using some sample sets and then connections between the pixels or neurons are determined. This way new images are segmented using this newly trained network [Dass, 2012; Khan, 2013; MengieZhang, 1997].

Thresholding is a simple but powerful technique that is used to create a binary image from a gray-level image. It is mainly used to separate the object from the background. The simplest method replaces each pixel in an image with a black pixel if the pixel(x,y) intensity is greater than or equal to threshold value i.e., \( f(x,y) \geq T \); else it is marked as white [Sharma, 2019; Khan 2013; Dass, 2012].

Region-based segmentation methods partition an image into regions that are similar according to some predefined criteria such as color, intensity, or object [4]. These methods are relatively simple as compared to edge detection methods but are computationally expensive. Segmentation methods based on the region are of three different types: region growing, region splitting, and region merging [Saini, 2014]. Region growing methods combines sub-regions into larger regions. Region splitting methods subdivide the regions that don’t satisfy homogeneity criteria. Region merging methods compare the neighboring regions and merge them if they meet
The criteria chosen [Kaur, 2015; Khan, 2013]. The region-based methods are used in medical images to find tumors, veins, etc. to find targets in satellite images/areal images, etc.

3. Literature Review:

Segmentation is typically associated with the pattern recognition problem. This is the first step in the pattern recognition process and is also called as Object isolation. It is a challenging task for poor or low contrast images that may result in diffusing tissue boundaries. [Kaur & Kaur, 2013]. It requires prior knowledge. Various methods of edge detection are proposed in the literature, but the selection of a particular method depends upon the type of image and the problem domain.

Ye, H. et al. [2018], proposed a new algorithm for edge detection of Remote sensing image using fast Guided filters to smoothen the image, then an improved Sobel operator of 3X3 mask and 8 direction template is used to find gradients and directions of the gradients. High and low thresholds are selected using a new two-dimensional Ostu method as the traditional method is very sensitive to noise and target size. The Dataset used for the experiment is the PNG image of the University of Chinese Academy of Sciences and the pixel size is 1280X659. The s/w is implemented using MATLAB 2016. Although the proposed algorithm gives more edge details, clear and continuous contours while the algorithm suffers from two limitations – high time complexity, inefficient for high-intensity noise.

Fawwaz, I. et al. [2018], compares the performance of Gaussian Filter and Bilateral Filter. The filters are applied to various satellite images using Canny, Robert, and Frei Chen. The advantage of a Bilateral filter over the Gaussian filter is that Bilateral filters use two kernel filters – Spatial kernel and Range kernel. The Spatial kernel is the distance between the pixels of an image. Range kernel is the similarity of intensity between the two pixels in the image. Two comparison parameters MSE and PSNR value are used. It was found that the higher the MSE value, the worse is the image quality while the higher the PSNR value better will be the image quality. They have used the satellite images of Sea and Lakes, applied Canny, Robert, and Frei Chen methods for different MSE and PSNR values on these images using Bilateral filters and Gaussian filters. Experiments show that Bilateral filters with the Canny operator with the lowest MSE value and highest PSNR values give the best result.
Zaaj I et al.[2018], proposed a hybrid approach for the extraction of building in Satellite image THR using feature detection. The Canny method is used to find borders of an object. If the image is noisy then the detection of contours is very difficult. Hence, Harris operator along with Canny is used to create a new method for Building Extraction. Building extraction from Satellite image THR requires the detection of edges and corners. The canny method sometimes can't detect all edge points. Harris operator is used for the detection of corners. Harris operator is used as a threshold determinant. The new combined method is used on different images with three different thresholds. The chosen thresholds are combined with the output of Harris. Results were found more effective for the higher threshold value.

Kumar N.S. et al.[2017], have used a three-stage process for road network extraction from high-resolution multispectral satellite imagery. Multispectral images are images with three or more spectral bands. The extraction of road features is necessary for urban planning, traffic management, maps updation, etc. The proposed method uses three steps for the extraction of road features. Edges are detected by using different edge detection operators (Canny, Sobel, Prewitt). Noise present in the resultant image is detected by using Morphological operation. Median filters are used to reduce the noise present in an image.

Guiming, S. et al.[2016], introduced an improved Canny algorithm, based on the disadvantages of the conventional Canny algorithm. The process is depicted in Figure 3.

The conventional method uses Gaussian Filters which sometimes detects the noise as an edge. High and low thresholds are selected manually hence it provides an incomplete edge. Improved Canny algorithm uses Morphological Filters for smoothening the image and provides accurate image contours. Using the Ostu method the two thresholds are chosen automatically which provides a clear and continuous edge. Both methods were applied on three different images to detect the edges of Lena and two Remote sensing images of road and ship. Figure 4 shows the result of the two methods for road edge detection. It is concluded that the improved Canny algorithm provides more accurate results than the conventional method.
Lavanya K. B. et al.[2014], has implemented the Sobel method on Simulink blockset and tested on three different images. Sobel technique is mainly used for implementation in hardware and real-time edge detection. The advantage of the Sobel method is less complexity and easy computation. The result of the Sobel operator is not accurate as it uses only two masks. Accurate results with Sobel operators can be obtained by using a larger set of masks.

K. Wang et al.[2014], proposed a new method for detecting edges of high spatial resolution Remote Sensing Images. The image is Fourier transformed to obtained magnitude spectrum, the analysis of spectrum is done by using radius and angle samples to identify edges. Two log Gabor Filters are multiplied with frequency spectrum and IFFT is applied on the result to detect the edges. Quickbird image of Nanjing Region, China is used for an experiment which gives good result.

Vijayarani S. et al.[2013], has described two different methods for detecting edges in facial images: Canny Edge Detector and Sobel Edge Detector. The advantage of detecting the edge of an image is to reduce the amount of data to be stored. In this research paper, both techniques are applied to a set of images and then the performance of the two techniques in terms of accuracy and speed are compared. After comparison, it is found that the Canny algorithm takes 34.7 sec, while Sobel takes 34.9 sec to detect the edge. Canny’s accuracy is 87.5% while Sobel’s accuracy 75%. It can be concluded that the Canny algorithm outperforms well when compared to Sobel Algorithm for edge detection.

Kaur G.S. et al.[2013], discussed recently proposed methods for automatic image segmentation. Applications of automatic image segmentation are in machine vision tasks such as object recognition, image compression, image editing, image searching, etc. Methods studied for
automatic image segmentation are Dynamic Region merging in which homogenous regions are merged iteratively according to some defined predicate.

Xi, J. et al.[2012], used Canny Operator and Hough transform for detecting edges of Remote Sensing Images. Remote sensing images contain a large amount of data that is corrupted with noise hence traditional methods are not effective for edge detection of Remote sensing images because traditional methods sometimes detect the noise as an edge and can also miss the real edges. Experiments show that the combined approach detects more accurate Edges of Remote sensing images.

Kaur, B.et al.[2011], used Mathematical Morphology for edge detection of ‘Saturn’ Image. Results are compared with Sobel Edge Detection, Canny Edge Detection, LOG, Prewitt edge detection. It has been observed that edge detection using mathematical morphology gives a better result than the traditional method. The proposed algorithm applied structure elements of various sizes in different directions with morphology operators. It selects and calculates the average of edges by taking the difference between eroded and dilated images in all directions.

Senthilkumaran, N. et al.[2009], explaind various methods of edge detection for image segmentation such as Robert, Prewitt, and Sobel. It also explains some soft computing approaches. The methods were applied to a real-life image of a university and it shows the output of the different methods.

Yi, L. et al.[2004], proposed a new algorithm for edge detection of the multi-source remote sensing image using fuzzy logic. Edge detection of Remote sensing images by conventional methods require complex calculations. In the proposed method, a new membership function is designed, modified the methods of fuzzy enhancement, and using edge evaluation criteria handles the iterative procedure automatically. Images of Landsat-7, Ikonos, Quickbird, and SPOT-5 are used for the experiment. It is concluded that the new method is more suitable for real-time application and edge detection of multisource and multi-temporal satellite images.

Zhang M.[1997], uses Neural Network for segmenting an image. Image features are used as input vectors. In this technique, object features that are to be segmented are identified by manual analysis of object samples, then programs are created. There are various types of Neural Networks: ART(Adaptive Resonance Theory) network, SIM( Self- organizing maps), and recurrent network. A sample neural network for segmenting an image is shown in Figure 5. Each pixel in an image corresponds to neurons. The training sample sets are used to train the neural
network to determine the connection and weight between nodes. Using this newly trained neural network, new images are segmented.

![Sample Neural Network Diagram](image)

**Figure 5: A sample neural network [Zhang M., 1997]**

Maini et al.[2009]; Jayakumar R. et al.[2014]; Dharampal et al.[2015]; Bala Krishnan K. et al.[2017]; author classified edge detection into two categories: *Gradient-based and Laplacian based*. The *gradient-based methods* detect the edges by finding the maximum and minimum values in the first-order derivatives of the image. *Laplacian based methods* detect edges by finding zero crossings in the second-order derivative of an image. These methods are often applied to the images that have been smoothed using Gaussian smoothing filters. *The gradient-based methods* mainly include a *Canny operator, Sobel operator, Prewitt operator, Robert’s Cross operator*. Among these methods, Canny is a more efficient algorithm for object extraction since it returns fewer false edges hence it is also called ‘*Optimal Edge Detector*’[17,18]. Sobel operator uses a pair of 3x3 convolution mask one is simply the other rotated by 90° as shown in Figure 6.

![Sobel Operator Masks](image)

**Figure 6: Masks Used by Sobel Operator [Jayakumar, 2014]**
Sobel operator returns edges at the points where the gradient of the image is maximum. The gradient is calculated using the derivative of Gaussian filters and detected Edges are refined using non-maximal suppression and hysteresis.

Partial derivative in X and Y direction is given by:-
\[
G_x = (P1 + CP8 + P9) - (P1 + CP2 + P3) \quad \ldots \ldots \quad (eq.1)
\]
\[
G_y = (P3 + CP6 + P9) - (P1 + CP4 + P7) \quad \ldots \ldots \quad (eq.2)
\]
The gradient of magnitude is given by:
\[
G[f(x,y)] = \sqrt{G_x^2 + G_y^2} \quad \ldots \ldots \quad (eq.3)
\]
The angle of orientation of the edge relative to the pixel grid which boost up the spatial gradient is given by:
\[
\theta = \arctan(G_y / G_x) \quad \ldots \ldots \quad (eq.4)
\]

Prewitt operator is similar to Sobel operator and is used to detect horizontal and vertical edges in an image. Robert’s cross operator performs a 2-D spatial gradient measurement on an image. The operator consist of a pair of 2X2 convolution kernels, one is simply the other rotated by 90°. 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. Bala Krishnan K. et al; Maini et al; also analyzed the performance of these edge detection methods using different parameters such as PR, PSNR, MSE and found that Canny method is computationally expensive but performs better compared to other methods under almost all conditions.

| S.No. | Author Name              | Method Used              | Methodology                                                                 | Pros and Cons                                                                                         |
|-------|--------------------------|--------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| 1.    | Ibtissam Z., Brahim C., El Khalil (2018) | Canny edge detection and Harris operator | Edges are detected by the canny algorithm and Harris operator is used to find the corners to improve building extraction. | Harris operator is reliable for corner detection. Corner information is lost when the threshold is large |
|   | Authors                          | Method                                                                 | Description                                                                                                                                                                                                 | Notes                                      |
|---|----------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|
| 2 | Fawwaz I., Zarlis M. & Rahmat R. F. (2018) | Bilateral filters and canny edge detection | Bilateral filters used spatial kernel and range kernel to smooth the image and reduce noise and edges are detected by the canny operator. Bilateral filters gives a more smooth image than Gaussian filters. |                                            |
| 3 | Ye H., Ding M. & Yan S. (2018)    | Edge detection using Fast guided filters | First, the image is smoothened using fast guided filters. Then a 3x3 and 8 direction template isotropic Sobel operator is used to find gradient and magnitude. Finally edges of high-resolution remote sensing images are detected using the Canny operator. Fast and accurate. High time complexity. Not suitable for high noise intensity |                                            |
| 4 | Kumar N. S., Sukanya B., Mohan B., & Prathibha, G (2017) | Canny,Sobel,Prewitt And Median filtering | Canny,Sobel and prewitt are used to detect edges of the road and the noise present in the image is removed using the median filter. It is a fast method. Median filters are often used to remove impulse noise. |                                            |
| 5 | Guiming S. & Jidong S. (2016)     | Improved Canny operator using Morphological operator | Composite morphological smoothening is used in place of Gaussian filtering. Then Ostu method is used for automatic threshold selection, Finally morphological structure elements are used to get more refined edges of remote sensing images. The traditional canny operator needs more calculations and also returns false edges. The improved method reduces the effect of noise and returns more accurate edges. |                                            |
| 6 | Lavanya K B ,K V                  | Sobel edge detection | Edges of three input | Easy computation and less |                                            |
| Reference | Technique | Details |
|-----------|-----------|---------|
| Ramana Reddy & Yllampalli (2014) | Sobel | Images are found using Sobel on MATLAB/SIMULINK. Less accurate when uses only two masks for the horizontal and vertical direction. |
| Wang K., Yu T., Meng Q. Y., Wang G. K., Li S. P., & Liu S. H. (2014) | Edge detection using two-dimensional log Gabor filter | Edge features of high-resolution remote sensing images are detected by log Gabor filters in the frequency domain. Good performance. |
| Vijayarani S., & Vinupriya M. (2013) | Canny edge detection and Sobel edge detection | Two methods are compared in terms of accuracy and speed. Canny is more accurate and fast as compared to Sobel. |
| Kaur B., & Garg A. (2011) | Mathematical morphological operator | Edges of Remote sensing image are detected by applying structure elements in various directions using morphological operators such as dilation, erosion, and the result is compared with Sobel, Prewitt, and canny. It is very simple and efficient for Hardware implementation. Noise can be suppressed and image can be enhanced. |
| Yi L., & Xue-quan C. (2004) | Edge detection using Fuzzy sets | A new membership function is designed and an edge evaluation criterion is used to automatically control the iterative procedure of image enhancement. Very useful in the processing of multisource remote sensing satellite images. Also suitable for low contrast images. |
| Zhang M. (1997) | Multilayer Feed Forward Neural network | Raw pixel data of small objects and backgrounds are used as input to a neural network. It can detect the small and regular objects. Difficult to detect the complex objects. |
4. Conclusion:

In this research paper various techniques of segmentation for remote sensing satellite images are described. Although various methods of image segmentation have been proposed but there is not any optimal algorithm that can be applied to any kind of image. The selection of a particular techniques depends upon the application. We find that canny method gives better result compared to the other methods of edge detection but sometimes canny gives us false detection of corner, hence Harris operator can be used for efficient corner detection. Also it has been observed that for image smoothening bilateral filters or morphological filters perform better than Gaussian filters. The choice of parameter for segmenting an image also plays an important role in feature detection. The choice of band for extracting certain features is also important. For linear feature extraction such as roads, buildings, boundaries, etc. the IR band was found suitable. Modified version of some of the gradient based approaches of edge detection have also been used in some research papers such as improved canny operator and improved sobel operator. Much work have been done using independent methods hybrid approaches can also be used for better results.

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