Comparative analysis of common edge detection techniques in context of object extraction

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ABSTRACT

Edges characterize boundaries and are therefore a problem of fundamental importance in image processing and particularly in automatic feature extraction. In this paper a comparative study of various edge detection techniques and band wise analysis of these algorithms in the context of object extraction with regard to remote sensing satellite images from the Indian Remote Sensing Satellite (IRS) sensors LISS-III, LISS-IV & Cartosat-I as well as Google Earth is presented. The comparison has been done between commonly used edge detection algorithms like Sobel, Canny, Prewitt, Roberts, Laplacian and Zero Crossing. Analysis results have shown that the Canny's algorithm is best suitable for the object extraction in most contexts due to fact that it yields less number of false edges, while Sobel is also a good option with lesser time and space complexity. The band wise analyses of the algorithms have also been done to find the suitability of band for the extraction of various features and it has been observed that linear features like roads, railway lines etc. can be detected more efficiently using infra red wavelength range images.

Keywords: Edge Detection, Remote sensing images, object extraction, Canny, Sobel, Prewitt Zero cross and Laplacian Edge detectors.

1. INTRODUCTION

Edges detection is a problem of fundamental importance in object extraction as it reduces image data and facilitates object detection [8] [9]. Edges identify object boundaries and are detected through abrupt changes in gray level above a particular threshold. Operators that are sensitive to the change in gray levels can be used as edge detectors. Literature reveals a great deal of edge detection techniques that can be generally classified in to three groups namely gradient, template and morphology based. Gradient based approach adopts a derivative operator to identify locations of large intensity changes. The second type resembles a template matching scheme, where the edge are modelled by a small image showing abstract properties of a perfect edge and falls under Laplacian based detection. The final type uses mathematical model of edges for detection and is a recent advancement in this context.

Sobel operator is one of the most commonly used detection methods and returns edges at points where the gradient of image intensity is maximum. Locations whose gradient value exceeds some threshold are declared edge locations [5]. Prewitt method finds edges using the Prewitt approximation to the derivative and returns edges at those points where gradient of

image intensity is maximum. Prewitt operator [22] does not place any emphasis on pixels that are closer to the centre of the masks. The Canny edge detector is considered as the standard methodology of edge detection [5] and it finds edges by looking for local maxima of the gradient of Image [7]. The gradient is calculated using the derivative of a Gaussian filter and the detected edges are refined with non-maximal suppression and hysteresis. This method uses two thresholds to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to be "fooled" by noise and more likely to detect true weak edges [6] [7]. The Laplacian method searches for zero crossings in the second derivative of the image to find edges since the second derivative is zero when the first derivative is at maximum [4]. However, this method is sensitive to noise, which should be filtered out before edge detection. Based on the filter used, the two methods namely Laplacian & Gaussian and Zero crossing are more popular and these are based on Gaussian filter and specified filter respectively [12].

Expansion Matching (EXM) method [19] [13] is a template matching approach that matches a given template with a given image by expanding the image signal in terms of non orthogonal Basis Functions (BF's) which are all translated versions of the template. A template matching edge detection method based on edge expansion matching was proposed by K.R. Rao et.al [13][18-21] in which authors suggested an analytical approach which is generalized so that it easily yields the optimal SNR operator for any desired edge model. The other contemporary methods follow the approach of defining a specific set of criteria for the given edge model and optimizing them in most cases, using numerical methods. The Step Expansion Filter out performs canny in terms of DSNR but canny optimizes a combination of SNR, localization and multiple suppression criteria and is optimal in that sense [13].

The availability of different bands have enhanced various analyses however certain bands are preferable for analysis of specific features. The edge detection operator are found to be sensitive to specific bands.In this paper we analyzes most commonly used Gradient and Laplacian based edge detection techniques for various satellite images in the context of object extraction. The basic factors of concern in the context of object extraction from satellite images are false edge detection, computational complexity depending on resolution, missing of true edges and problems due to noise etc. In this paper analysis on commonly used edge detection techniques (Gradient and Laplacian based Edge Detection) has been presented for various spatial resolution remote sensing satellite images. The comparative advantages and disadvantages of one method over another have been done by visual comparison of ground features as well as field visit assisted with DGPS instrument/mobile mapping system. The band wise analysis is also conducted to find more appropriate band for evolving optimum edge detection methodology. The sensitivity of different detection techniques with reference to spatial resolution is also investigated.

2. DATA RESOURCES AND STUDY AREA

The investigations of present research work have been carried out for the satellite images of different spatial resolution sensors for the Bhopal city in India and details are given in the table-1. The study area is new market area of Bhopal city having area central point coordinates 23° 55' N Latitude and 76° 57' E Longitude. Various edge detection algorithms have been implemented in the MATLAB software environment. The Erdas-Imagine v9.1 was also used for the pre-processing of images and other image analysis tasks.

Table 1: Details of satellite images used for analysis

S.No.	Imaging sensor	Spatial resolution(m)	Satellite	Area	Date of Image Acquisition
1	PAN	2.5	IRS-P5(Cartosat-1)	Bhopal (India)	5th April 2009
2	LISS-III	24	IRS P6	Bhopal (India)	5th April 2009
3	LISS-IV	2.5	IRS P5 (Cartosat-1)	Bhopal (India)	16th March 2010
4	Google Earth	NA	NA	Bhopal (India)	16[th]March 2010
5	LANDSAT-5TM	32.6	LANDSAT	Bhopal (India)	26th Dec 1990

3. METHODOLOGY AND RESULTS OF INVESTIGATIONS

The satellite images of study area have been selected in such a way that they cover some known different land use ground features with well defined and arbitrary geometry as mentioned in the investigation result tables. The important component of any edge detection method is the selection of parameters like threshold value, kernel, intensity interpolation method etc. Different edge detection techniques were analyzed using different sample images with regard to the context of object extraction. It was found that certain features can be better extracted using specific algorithms. The complexity analyses of the various edge detection methods were done using standard analysis techniques.

The parameters that we used for analysis are the ideal threshold value for the detection of the various images, the noticeable features in the edge image etc. The minimum value of threshold below which the features are not distinguishable and the maximum value of threshold above which the edges will get eliminated are determined for each of the satellite images and found that the values vary as a function of resolution as well as the edge detection techniques used. The best threshold value is also determined for each of the algorithms with reference to each satellite images. The images are subjected to various edge detection methods and a visual comparison of the results is given in the following paragraphs.

3.1 Analysis of LISS3 sensor image

The LISS3 sensor image was subjected to various edge detection methods and the results are given in the Figure 1. The threshold value ranges for the detection of edges formed by various ground features are also presented in the Table-2.
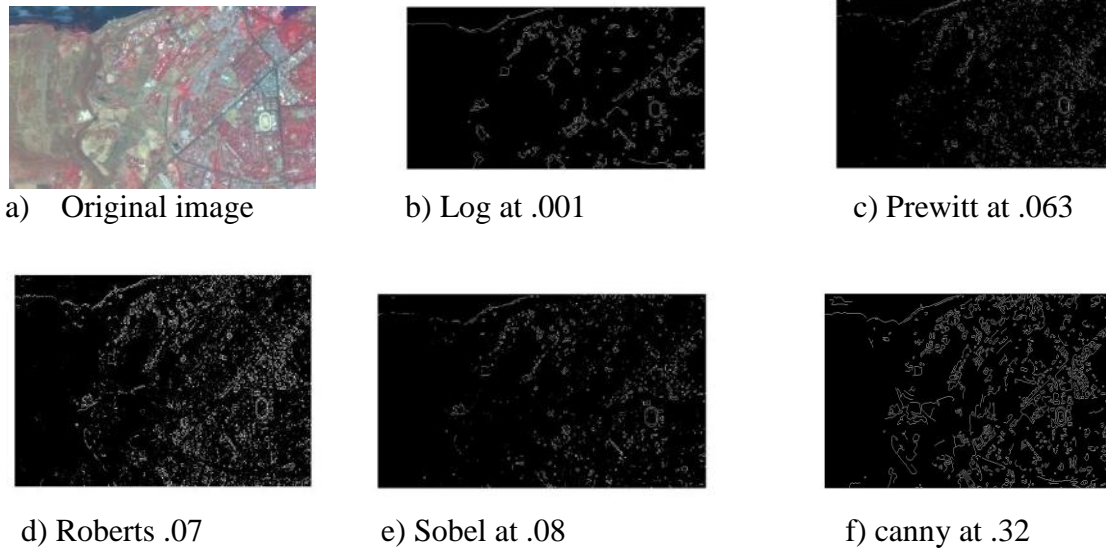
| a) Original image | b) Log at .001 | c) Prewitt at .063 |
| d) Roberts .07 | e) Sobel at .08 | f) canny at .32 |

Figure 1: Input image and detected edges using various methods (a) to (f)

As shown in the above detected edge image as well as Table 3, more features were distinguished, when canny was used and there was not much difference in time and space complexity for the various algorithms.

Table 2: Analysis result of Edge Detectors for LISS3 image

S. NO	Algorithm for edge detection	Threshold values			Distinguished Features on the edge image
		min	Ideal	Max	
1	Sobel	0	0.0515	0.3800	Stadium, Lake
2	Canny	0	0.3500	0.8600	Roads, Stadium, Lake
3	Robert	0	0.0533	0.2800	Lake
4	Prewit	0	0.0506	0.3400	Lake
5	Laplacian of gausian	0*	0.0025	0.2100	Lake
6	Zero crossing	0*	0.0025	0.2300	Lake

3.2 Analysis of LISS4 sensor Image

The LISS4 sensor image was subjected to various edge detection methods and the results are given in the Figure 2. The threshold values for the detection of edges formed by various ground features are also presented in the Table-4
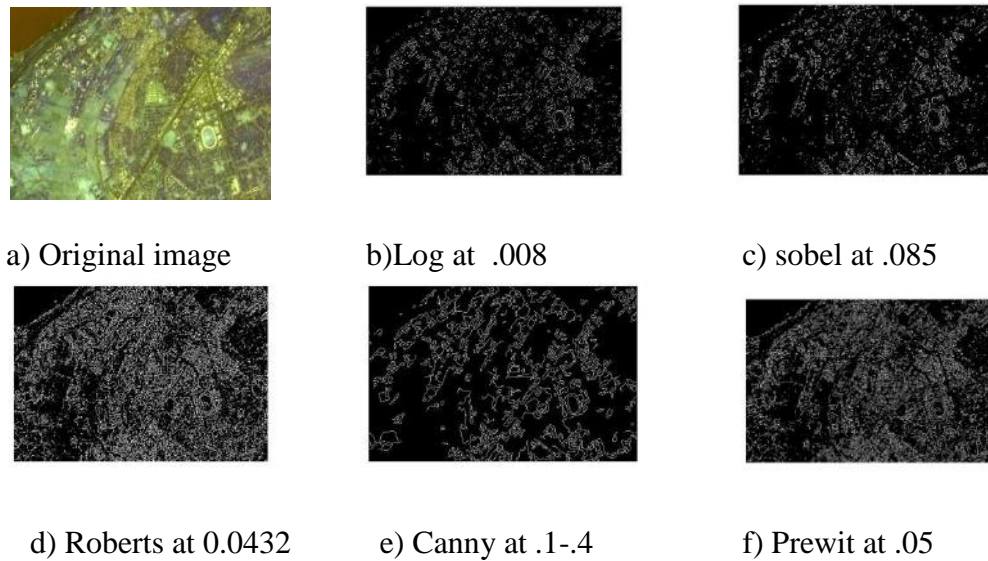
| a) Original image | b)Log at .008 | c) sobel at .085 |
| d) Roberts at 0.0432 | e) Canny at .1-.4 | f) Prewit at .05 |

Figure 2: Input image and detected edges using various methods (a) to (f)

As shown in the Table-3 the performance of Canny and sobel are almost same and Sobel is computationally simple.

Table 3: Analysis result of edge detectors for LISS4 image

S.NO	Algorithm	Threshold			Distinguished Features
		Min	Ideal	Max	
1	Sobel	0	0.0753	0.2000	Roads, Stadium, Lake
2	Canny	0	0.0250-0.0625	0.4750	Roads, Stadium ,Lake
3	Robert	0	0.0887	0.3400	Lake
4	Prewit	0	0.0736	0.2800	Lake
5	Laplacian of gausian	0*	0.0032	0.3000	Lake
6	Zero crossing	0*	0.0032	0.3000	Lake

The roads can be extracted to some extent using canny but breaks are there due to disturbances as shadow. The Zero crossing methods can detect the stadium areas and water bodies but the gradient methods are preferred.

3.3 Analysis of Google earth image

The Google Earth image was subjected to various edge detection methods and the results are given in the Figure 3. The threshold values for the detection of edges formed by various ground features are also presented in the Table-4.
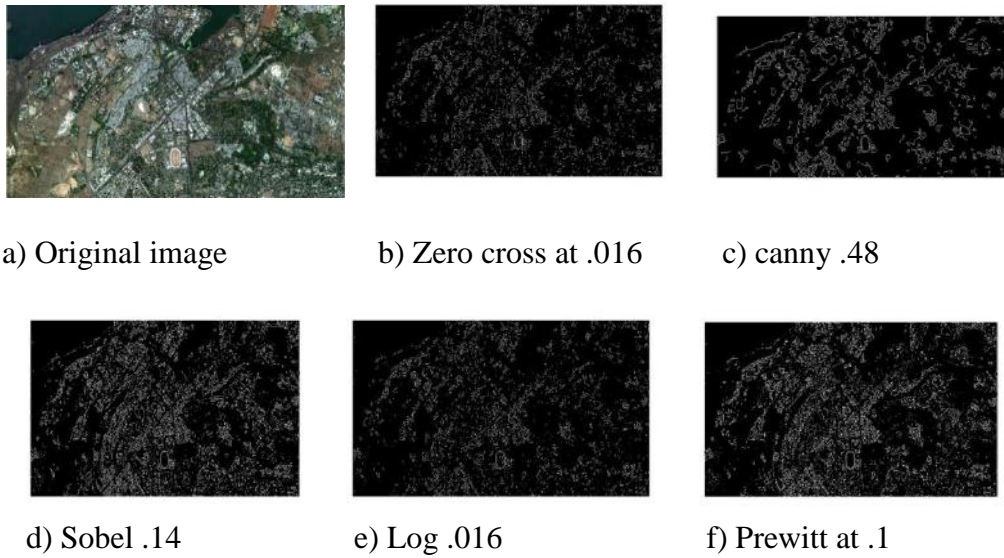
a) Original image   b) Zero cross at .016   c) canny .48

d) Sobel .14   e) Log .016   f) Prewitt at .1

Figure 3: Input image and detected edges using various methods (a) to (f)

The results of the analysis are summarised in the table-5 and it is evident that Canny is giving better results as compared to Sobel which is more prone to false edges. However, the computational and space complexity of canny is more when compared to others.

Table 4: Analysis result of edge detectors for Google earth image

S.NO	algorithm	Threshold			Distinguished Features
		Min	**Ideal**	**Max**	
1	sobel	0	0.2044	0.5600	Roads, Stadium
2	canny	0	0.0813 0.2031	0.6300	Roads, Stadium, Lake, Buildings, vehicles
3	robert	0	0.2521	0.4100	Lake
4	prewitt	0	0.191	0.2300	Lake
5	Laplacian of gausian	0*	0.0088	0.2000	Lake
6	Zero crossing	0*	0.0088	0.2400	Lake

3.4 Analysis of PAN sensor image

The PAN sensor image was subjected to various edge detection methods and the results are given in the Figure 4. The threshold values for the detection of edges formed by various ground features are also presented in the Table-5
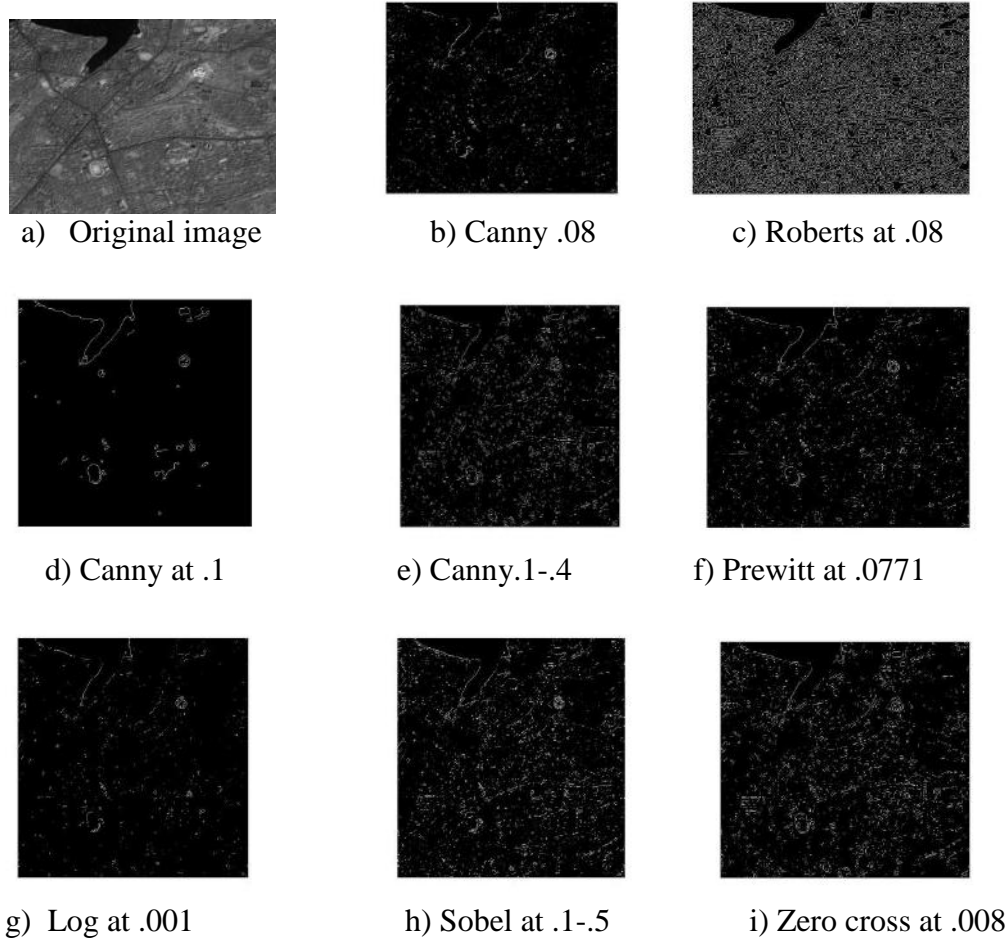
| a) Original image | b) Canny .08 | c) Roberts at .08 |

| d) Canny at .1 | e) Canny.1-.4 | f) Prewitt at .0771 |

| g) Log at .001 | h) Sobel at .1-.5 | i) Zero cross at .008 |

Figure 4: Input image and detected edges using various methods (a) to (i)

The above analysis indicate that the Canny can be used to detect the detailed objects from PAN images and the features extracted, threshold values are as given

Table 5: Analysis result of Edge Detectors for PAN sensor image

S.NO	algorithm	Threshold			Distinguished Features
		Min	Ideal	Max	
1	sobel	0	0.0797	0.3000	Roads, Stadium, Lake
2	canny	0	0.0563 0.1406	0.3500	Roads, Stadium, Lake, Buildings
3	robert	0	0.0892	0.2400	Lake
4	prewit	0	0.0771	0.3100	Lake
5	Laplacian of gausian	0*	0.0043	0.2000	Lake
6	Zero crossing	0*	0.0043	0.2000	Lake

The analysis confirms that the PAN image can be used to detect the, water bodies using canny or sobel where canny is preferred. The false edges are more at low threshold and ideal threshold causes the elimination of various weak edges.

3.5 Analysis of CARTOSAT

The CARTOSAT image was subjected to various edge detection methods and the results are given in the Figure 5. The threshold values for the detection of edges formed by various ground features are also presented in the Table-6
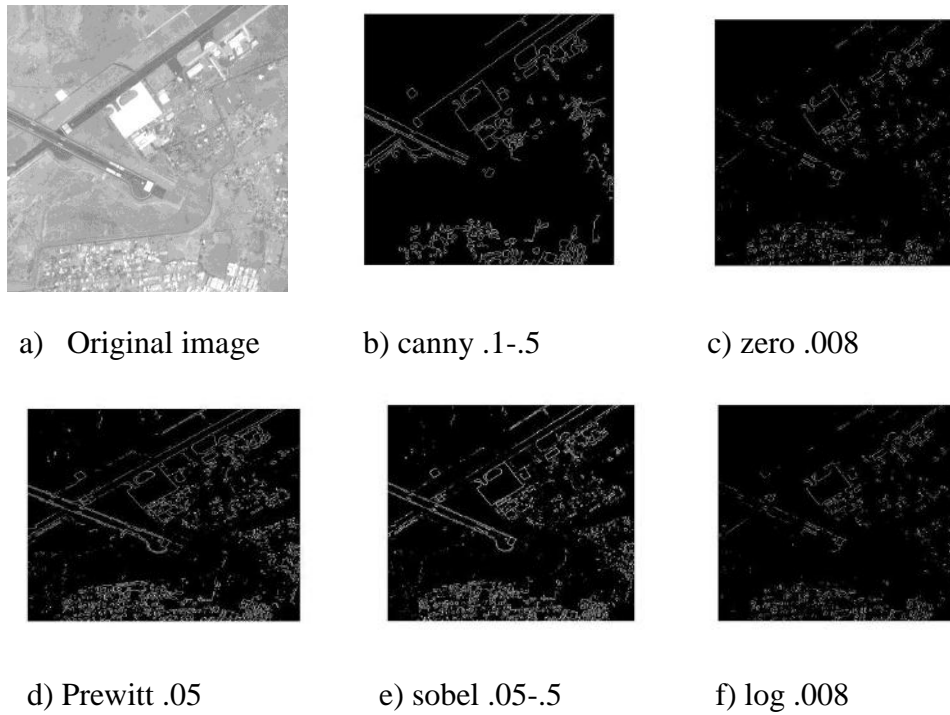
a) Original image   b) canny .1-.5   c) zero .008

d) Prewitt .05   e) sobel .05-.5   f) log .008

Figure 5: Input image and detected edges using various methods (a) to (f)

Table 6: Analysis result of Edge Detectors for CARTOSAT image

S.NO	Algorithm	Threshold			Distinguished Features
		Min	Ideal	Max	
1	Sobel	0	0.0797	0.3000	Roads
2	Canny	0	0.0563 0.1406	0.4000	Roads, Stadium, Lake, Buildings, Vehicles
3	Robert	0	0.0892	0.1500	Lake
4	Prewitt	0	0.0771	0.2300	Lake
5	Laplacian of gausian	0*	0.0043	0.2150	Lake
6	Zero crossing	0*	0.0043	0.2340	Lake

The analysis confirms that the CARTOSAT image due to its high resolution is best suited for the, detection of features. Features as water bodies can be detected using canny or sobel where canny is preferred. The false edges are more at low threshold and ideal threshold causes the elimination of various weak edges

4. BAND WISE ANALYSIS

The images were analysed band wise also to determine the sensitivity of various edge detection algorithms to image acquisition wavelength range. Based on the basic analysis we found that the Canny & Sobel are giving better results, hence only these were used for the present investigations. The LISS-3 and LISS-4 images have been used for the analysis due to fact that only these sensors are providing multispectral images.

4.1 Analysis of LISS 4 image bands

a) Original Band 1 image   b) canny .1-.3   c) sobel .1-.3

d) Original Band2 image   e) canny .1-.3   f) sobel .1-.3

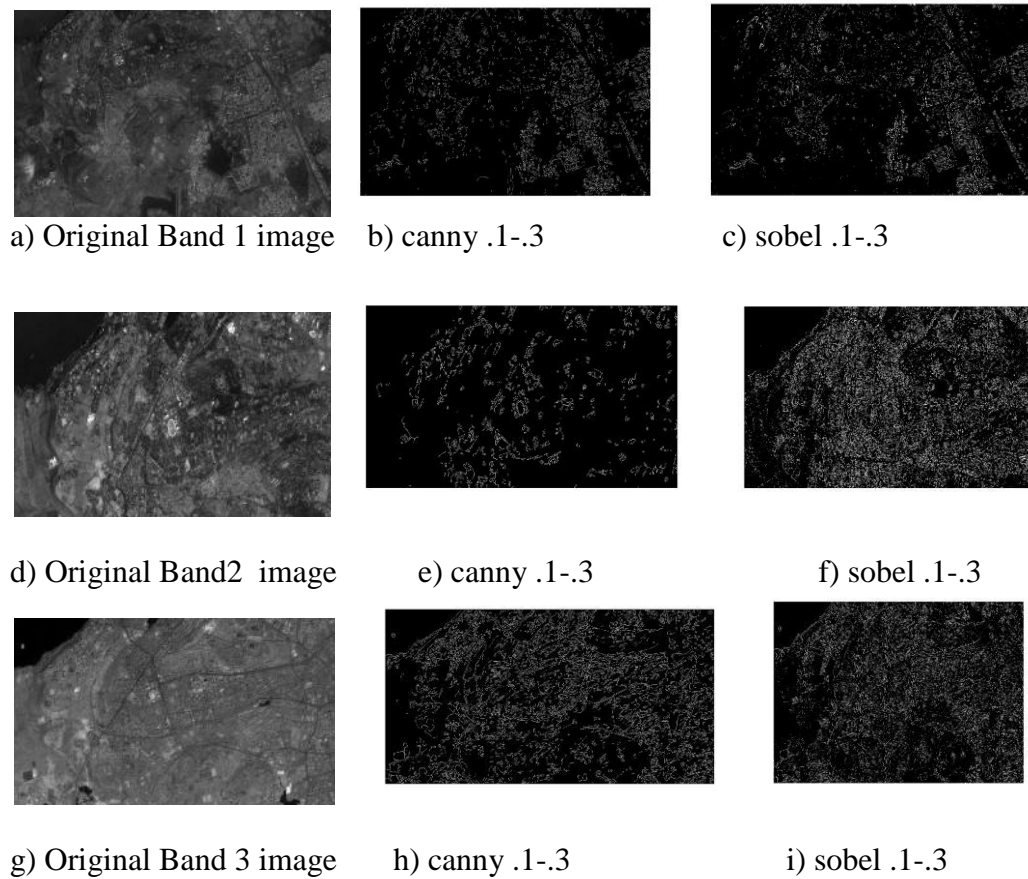g) Original Band 3 image   h) canny .1-.3   i) sobel .1-.3

Figure 6: Edges detected from different band LISS-3 sensor images (a) to (i)

The above analysis has confirmed that the roads can be best distinguished in band 3 and thus for extracting the roads, buildings, similar features band 3 images should be preferred.

4.2 Analysis of LISS 3 image bands

a) Original B1 image   b) Canny at .1-.25   c) Sobel .02

d) Original B2 image   e) Sobel at .02   f) Canny at .15

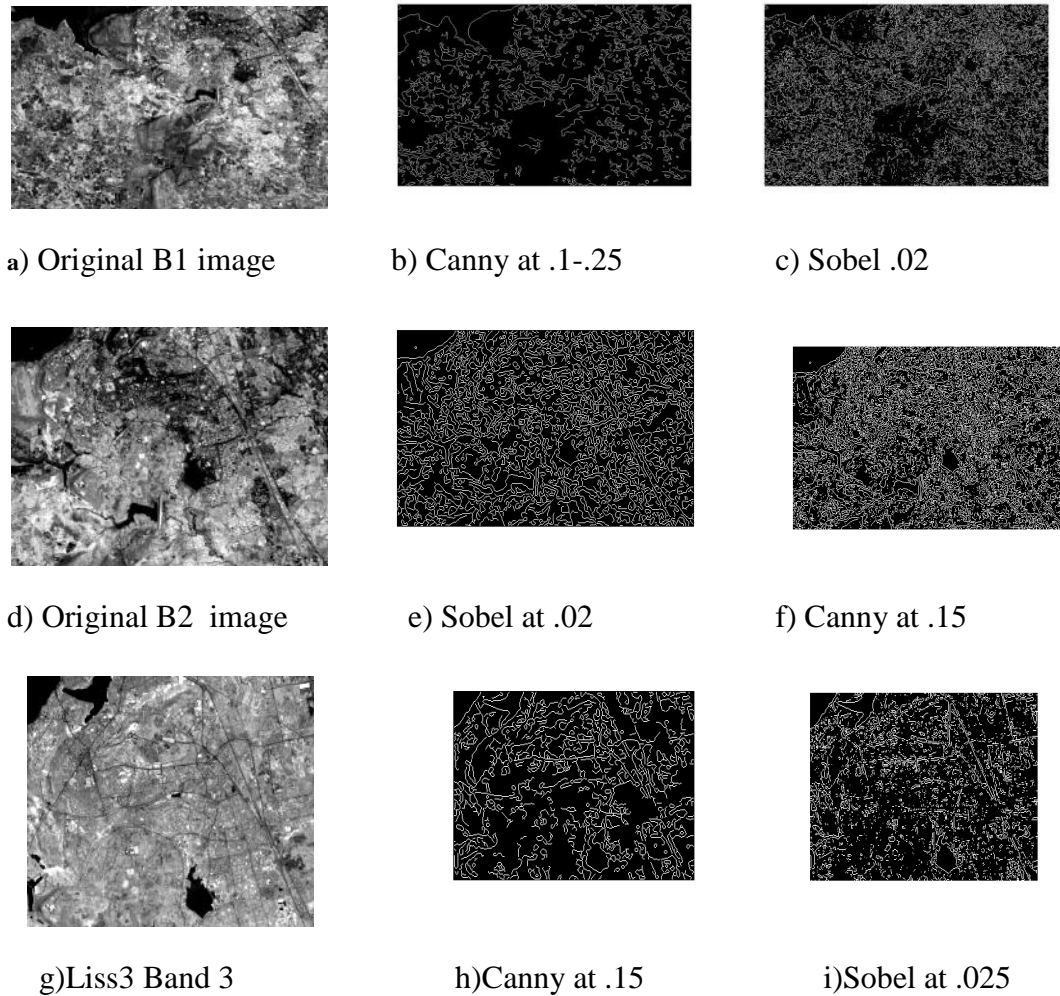g)Liss3 Band 3   h)Canny at .15   i)Sobel at .025

Figure 7: Input image and detected edges using various methods (a) to (i)

The band wise analysis of LISS 3 images also confirms that Band3 (Infra Red Region) images are suitable for the extraction of various natural features as vegetation and also for manmade features as roads, buildings etc.

5. SUMMARY OF ANALYSIS

The investigations of various spatial resolution images using different edge detection methods have shown that the Laplacian based (second order) methods are more sensitive to noise than their gradient based counterparts. The comparison of each edge detection algorithm revealed that the various features can be efficiently extracted from the satellite images using Canny but Canny is computationally more complex as it takes more time as well as space. The analysis details are presented in table 7.

Table 7: Analysis result of Edge Detectors

S.NO	Opertor	Complexity		Noise sensitivity	False Edges
		Time	Space		
1	Sobel	lower	high	Less Sensitivity	More
2	Canny	high	high	Least Sensitivity	Least
3	Robert	high	high	Sensitivity	More
4	Prewit	low	lower	Least Sensitivity	More
5	Laplacian of Gausian	low	least	Least Sensitivity	More
6	Zero crossing	low	less	Least Sensitivity	More

Sobel also detects the various features and is computationally more efficient as Canny but with more false edges. The other algorithms as Robert and Prewitt also detect the various features and stadium but fails in case of smaller features and the range of usable threshold is very low. The band wise analysis of the system confirms that certain bands are suitable for certain features as Infrared band for road networks, vegetation and Band2 for water bodies, buildings.

6. CONCLUSIONS

The investigations of present research work have led following conclusions:

1. Canny method out performs all the other methods even though its computational complexity is higher. Canny can be used for the extraction of even objects with feeble edges.
2. The Sobel also detects the various features and is computationally more efficient as Canny but with more false edges. Sobel is optimum for objects with Strong edges as lakes, Stadium etc.
3. The other algorithms as Robert and Prewitt also detect the various features and stadium but fails in case of smaller features and the range of usable threshold is very low.
4. For any method of edge detection, the computational complexity increases with the increase in the spatial resolution.
5. Also, it was found that for the extraction of certain features certain bands should be used as the response of these features to these bands are high. The IR band was found to be suitable for extraction of linear features as roads, buildings, boundaries etc. The ground truth verification confirmed that the edge detection is affected by shadows, salt and pepper noise among which the latter can be eliminated by using appropriate low pass filter.

7. REFERENCES

[1] Parker J. R., "Algorithms for Image processing and computer vision," 2nd Edition, Wiley publishers, 3-15, 2010.
[2] Milan S, Vaclav H, and Roger B, "Image processing, analysis, and machine vision, second Edition," Thompson Learning, pp. 82-90, 2009.
[3] Raman M, and Himanshu A, "Study and Comparison of Various Image Edge Detection Techniques," *International Journal of Image Processing (IJIP),* vol.3, no.1, 1993.

[4] Min C. Shin, Dmitry B. Goldgof and Kevin W. Bowyer., "Comparison of Edge Detector Performance through use in an Object Recognition Task," *Computer Vision and Image Understanding*, vol. 84, pp 160–178, 2001.

[5] Min C. Shin, Dmitry Goldgof, and Kevin W. Bowyer., "An Objective   Comparison Methodology of Edge Detection Algorithms Using a Structure from Motion Task," *IEEE Transactions of image processing*, 1998.

[6] Min C. Shin, Dmitry B and Kevin W., "Comparison of Edge Detection   Algorithms Using a Structure from Motion Task," *IEEE transactions on systems, man, and cybernetics-part b: cybernetics*, vol. 31, no. 4, 2001.

[7] Canny J. F., "A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligenc*e, 8(6):769–798, November 1986.

[8] Hong Shan N, and Asher H, "Adaptive Edge Detection for Real-Time Video Processing using FPGAs," GSPX conference, 2004.

[9] Harris, C. and Stephens M. 1988, "A combined corner and edge detector," Fourth Alvey Vision Conference, Manchester, UK, pp. 147–151.

[10] Gemignani V, Demi M, Paterni M, Giannoni M, and Benassi A, "DSP implementation of real time edge detectors," *Proc of speech and image processing,* pp. 1721-1725, 2001.

[11] Melgar, I, Fombellida J, Gomez J, Seijas J, "Edge detection algorithms in intensity SAR images: Empirical comparison of performances and proposed improvements," Automation Congress, World , vol., no., pp.1,7, Sept. 28 2008-Oct. 2 2008.

[12] Didier Demigny, "On optimal linear filtering for edge detection," *IEEE Transactions on image processing*, vol.32, no.3, pp. 728-737, 2002.

[13] K.R. Rao,J.Ben-Arie., Optimal Edge Detection using Expansion Matching and Restoration, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 16, no. 12. pp: 1169-1182, 1994.

[14] Allan Jepson., Lecture notes, Department of Computer Science, University of Toronto, 2010.

[15] Anil K. Jain., "Fundamentals of digital image processing, Prentice-Hall, Inc. 3rd Edition," pp.120-123, 2009.

[16] William K. Pratt., "Digital image processing," John Wiley & Sons, Inc., New York, 2004.

[17] Ehsan N., "Edge Detection Techniques: Evaluations and Comparisons," Lecture notes, Department of Computer Engineering, Faculty of Engineering, Mazandaran Institute of Technology, 2010.

[18] J. Ben-Arie and K. R. Rao., "A novel approach for template matching by non-orthogonal image expansion," *IEEE Trans. Circuits Syst. For Video Technol*., vol. 3, no. 1, pp.71-84, 1993.

[19] J. Ben-Arie and K. R. Rao., "optimal template matching by non-orthogonal image expansion using restoration," *International Journal of Machine Vision and Applications*, 1994.

[20] J. Ben-Arie and K. R. Rao., 1993, "Image expansion by non-orthogonal basis functions   extended for optimal multiple template matching," *Proc. IEEE Int. Conf. Acoustic,   Speech, Signal Processing*, Minneapolis, MN, pp. 145-148, 1993.

[21] Rao K. R., and Ben-Arie J., 1993, "Generic face recognition, feature extraction and edge detection using optimal DSR expansion matching*," Proc. IEEE Int. Symp. Circuits Syst*., Chicago, 1993.

[22] Muthukumar V, and Daggu V. R **., "**Hardware Acceleration of Edge Detection Algorithm on FPGAs

[23] Raman Maini, Sohal J.S., "Performance Evaluation of Prewitt Edge Detector for Noisy Images," GVIP Journal, vol.6, no.3, pp.45-50, 2006.

[24] Roberts L., "Machine Perception of 3-D Solids," *Optical and Electro-optical Information Processing*, MIT Press, 1965.

[25] Rao K. R., and Ben-Arie J., "Edge detection and feature extraction by non-orthogonal image expansion for optimal discriminative SNR," *Proc. IEEE Conf. Computer Vision*, pp.120-123, 1993.