ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 2, February 2018

Automation of Building Extraction from Satellite Imagery Using Line Segment Detector

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***Abstract* - This paper focuses on an automatic algorithm for fast building boundary extraction from satellite imagery and it presents an experimental comparison of the bilateral filter (BF) and adaptive bilateral filter (ABF). The study and experimental result prove that outcomes of ABF are much better than outcomes of BF. ABF produces a more promising result than BF. Old and conventional building boundary extraction models are very complex and time-consuming. The proposed procedure of building boundary extraction consists of three main stages: (1) Edge-preserving and smoothing by using adaptive bilateral filter, (2)detection of a line segment using ED Line algorithm, (3) identification of polygonal building boundary by using perceptual grouping technique. Our proposed algorithm is tested on HR (high resolution) Quick Bird satellite images and obtained results are promising and nearly real-time. Hence the experimental results are useful enough with an overall accuracy of 88.24%, which is accurate enough for further image understanding building boundary detection and identification of the target in real time environment and can contribute to solving the problem of identification of unauthorized and illegal building construction on its early stage.**

Keywords: Quick Bird satellite imagery, Adaptive bilateral filter (ABF), bilateral filter, high resolution satellite image, Histogram equalization, ED Line Detector algorithm, Building boundary extraction.

I. INTRODUCTION

Urbanization is most important part of global environmental growth and changes. it effects environment in various aspects. The unauthorized and illegal development is huge and continuously growing problems in various developing countries (like India) that are rapidly urbanizing. Such constructions are more harmful for environment and urban planning. So the growth of urbanization should be in monitored and proper way. To monitor growth of urbanization and to preserve government plan and policies we required a system which can be able to detect construction on regular basis. This system should be capable enough to identify such unauthorized and illegal construction . Timely and early stage identification of such construction is very important. So that lot of damage and loss of government policies may be prevent. But It is difficult to control such construction with the help of long term traditional (annual or multi-year) monitoring system which are existing nowadays. Therefore it is important that to have a full-proof and accurate system which informs the authority during the beginning of such construction so that it may be compounded at the earliest. The primary stage of such supposed system is accurate identification of building boundary or rooftop by using image processing technique. but it has been very complex and tedious task since starting. Since various technique and algorithms have developed in last few years to automate the task of building boundary detection and extraction. But in urban area there are so many other subjects in close proximity like tree, power lines, vehicles and parking lots.These subjects may create confusion and occlude the building's rooftops and effect the accuracy level of the algorithm. So this system should also be capable enough to distinguish among such object and building structure. In real world accuracy level always expected to be very high . This is the reason that accurate building boundary detection and its extraction is very important and useful.

2 .BACKGROUND

The early building extraction was based on human vision or human perceptions which include shape, space, spatial arrangement, illumination, and shading and reflect for feature extraction phase. Many applications were developed which uses a semi-automatic technique for extraction of point, line, polygon some and other complex object [1]. Some mechanism were developed and used for road extraction [2].After some time user became able to specify the approximate location of object and the computer perform a specific task to locate boundaries of building like seed growth algorithm. In this algorithm user defined starting point and growth according to value similarity between pixels. At the same time another technique were developed as an alternative the approach similar to above were developed in which manual digitations of one image is done and bi- polar geometry between stereo pair were used to locate the height and

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 2, February 2018

corresponding point in second image [3]. In another research work author have used two or more panchromatic images for extraction of flat or symmetric gable roof rectilinear building. These types of images do not need to be stereo pairs. [4].At the same time period another research was carried out in which author has used both multi view stereo and color information. The achievement of this approach was the improvement in detection rate which was gained by applying the detection algorithm on different view images of same object and it was more accurate than before [5]. In another research work author Cord focus on the problem of automatic detection and extraction of building and modeling from the high resolution(less than 10cm per ground pixel) stereoscopic aerial images [6] At first fraser discover the ability to extract building manually from IKONOS satellite imagery to construct a urban area map and 3D model. He found that about 15% of building was not identifiable in imagery [7]. In another simultaneous work a snake based approach was used, to detect and extract two Dimensional building boundary from high resolution IKONOS satellite images[8]. During the same century in another research work author used a semi-automated method which was based on the combination of two techniques named as active contour model (snakes)technique and dynamic programming optimization technique. This procedure was used digital surface model and an Ortho image[9]. In 2003 lee carryout out a research work and proposed an approach in which a classification based technique was used to extract building edges and rooftop from the multispectral and panchromatic images of satellite named as IKONOS [10].During the same time another approach was proposed in which a methodology was used. In this methodology an object-based and fuzzy pixel-based approach was used to perform classification of the pan-sharpened IKONOS satellite images. In this methodology primarly fuzzy pixel-based classification was done. After that the segmentation was performed on images and then at last stage the required features were derived from the image which was segmented previously [11].In another approach author developed the classification and feature extraction technique in which panchromatic satellite images were used. [12].In [13] and [14] Baltsavias and Brenner conducted the research for automatic and semi-automatic building extraction approaches. In 2005 a research work war carried out by sunar in which a land-use map was designed and developed for current status of a specific urban area by using high resolution satellite images of that particular urban area and proved that these type of images can be used to extract land development information .This work have evolved the idea that such type satellite images can be used in urban planning and monitoring system[15]. In 2006 another approach was came into existents in which three data sources were used to extract 3D view of the building[16]. After that another approach was developed by author for the automatic detection and extraction building boundaries of rectangular and circular shaped building from satellite images. This approach was used Hough transform technique. In the methodology proposed by author first of all the binary Support Vector Machines classification technique was used to detach candidate building patches from IKONOS imagery. After that edges are detected from building patches using canny edge detection algorithm. At final step edged image was converted into vector form with the help of the Hough transform technikque. But with this approach the problem was that the success of this approach is dependent on the effective and error free detection of the building patches [17]. In another approach author presents an effective satellite image processing method for counting the no of trees. It is done by using Texture approach .This approach converts a remotely sensed image into HRSI images (for more qualitatively analyze the image data). The texture differences between the saturation channel and intensity channel is effective and awesome method to detect the tree crowns in complete seen images. The problem with this approach was dense canopies complicated entities presents in images and Shadow [18]. In another research author discussed about road network extraction. Author had found that HRS Imagery can play an important role in urban construction's database creation, refinement and updating. In this proposed research work author have developed an effective approach for road network extraction using high resolution satellite imagery.The technique developed by authors performs the segmentation of the images with the help of multi-resolution object oriented segmentation. This method concentrate on reveling both type of information either spatial or spectral. these information is necessary for target extraction. A fuzzy classifier is used for automatically road region identification. In the proposed technique authors has used HR satellite images having resolution 0.5 to 1.0 m. To perform experiment they have used fused IKONOS 2, Quick bird, Worldview product [19]. In another research author presents a study report that uses RADARSAT-2 satellite images. Revisit time of this satellite is 24 days.The methodology used by author consist three steps-(1).Preprocessing of satellite images.(2)Investigation of the ability of satellite imagery in land cover classification.(3) Detection of land

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
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development from a pair of successive RADARSAT-2 satellite images images. Author has founded that the satellite images are much more capable to detect changes into land categories. Author has categorized land into five categories (a).vegetation area, (b).water bodies, (c).bare/sparsely vegetated area , (d).paddy fields,(f).Built-up areas. In this research author has found that the paddies are main cause which creates problem. [20]. In another research during the same time period author has developed a technique which was based on mathematical morphology technique for a building detection . The author's proposed method is unsupervised and it doesn't require any additional data. It uses several morphological operations. The author focus is on built region detection. And for this purpose he used Hit and Miss Transform (HMT) which is based on mathematical morphology. Problem with this method is that it was a semi-automated method and authors suggest that in future it is possible to create an automatic thersholding technique which automat the full method [21]. During the same time period another study was carried out in which author had proposed a technique in which extraction of building information from satellite imagery (of high-resolution) is done with the help of a technique named as object-based based image analysis (OBIA), or geographic object-based image analysis. In the proposed technique authors has used the concept of object oriented classification using high-resolution satellite data for automatic building extraction. The problem with these techniques is that clear edges of building were not extracted .It coincides with the original images and some confusing factors are generated [22].

3. METHOD FRAMEWORK

In the proposed procedure, a new method is presented to extract the building automatically for VHR satellite imagery based on EDlines, a line detector and perceptual grouping. The proposed approach consists of three main phases: In the first phase of this method, Histogram equilibrium increases the contrast of the image and adaptive bilateral filter surprisingly improve the detection accuracy of building boundary by edge preserving , smoothing and noise reducing. Adaptive Bilateral filter is better than bilateral filter[23] for the edge preserving smoothing. PSNR value is reduce by almost one fourth by adaptive bilateral filter compared to bilateral filter. At the Second phase EDlines algorithm is used for line and contours detection of building, At third phase perceptual contour line analysis is done to find polygonal building boundaries and outline. The combination of EDlines algorithm based on Edge drawing and perceptual contour line analysis provides almost real-time and batter experimental results. The framework of the proposed procedure is given in Fig. 1. There are three main steps in our proposed methodology

- preprocessing of satellite image
- Line Segment Detection using EDline algorithm
- Perceptual Grouping for line linking

At first stage, a satellite imagery of very high resolution is preprocessed by histogram equalization and a ABF [24] Histogram equilibrium increases the contrast of the image and adaptive bilateral filter amazingly improve the accuracy level of boundary detection by edge preserving smoothing and noise reducing It is a new technique for sharpening and smoothing of an image. Secondly, EDlines, algorithm[25] is used for line detection based on Edge drawing[26] to track building contours . ED Lines algorithm is a linear time line part detector which draws edge by using clean and contiguous chain of edge pixels. Finally, perceptual grouping is applied to detect building boundaries.So perceptual grouping is process of determining which specific regions and which specific parts of the visual sight belong together as parts of higher order perceptual units. Hence In short our proposed methodology is implemented in three parts. In first part Adaptive Bilateral Filter and histogram equalizer is used to preprocess satellite image. For very high resolution satellite image these two techniques are used for sharpness enhancement and noise removal.In second part EDlines algorithm is used to detect the lines in all the images. And in third part perceptual grouping is used for final extraction of buildings from satellite image

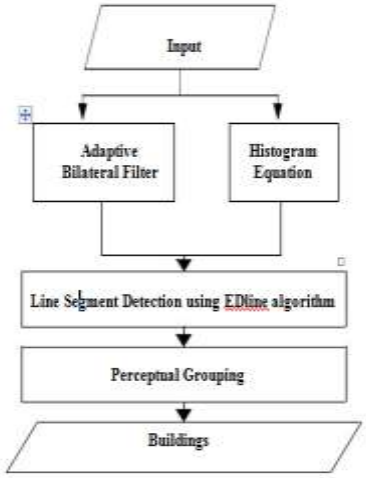

Fig 1. The workflow of the proposed Technique

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
Vol 5, Issue 2, February 2018

4. PROPOSED METHOD

Hear we are proposing a method in which we use a framework which is based on detection of small line segment from VHR satellite image.For LSD detection a combination of EDlines, algorithm for line detection, based on Edge drawing and perceptual contour line analysis, is used which gives almost real-time and more accurate experimental results

4.1 Preprocessing

In this preprocessing of VHR image some factors of image like edge preserving, smoothing and noise reducing have been taken into consideration, Histogram equilibrium increases the contrast of the image and adaptive bilateral filter improve the accuracy level of boundaries detection by noise reducing , smoothing and edge preserving. Adaptive Bilateral filter is better than bilateral filter for the edge preserving smoothing. ABF is an enhancement and improvement in bilateral filter. It is a new technique for sharpening and smoothing of an image. The Adaptive bilateral filter in its numerical form is shown at the bottom -Bilateral filter is a nonlinear filter that is used for image preprocessing it is able to remove the noise of image while preserving edge structures. Bilateral filtering is an enhancement over a conventional linear low-pass filter Gaussian filter But ABF is an enhancement over BF. It is a new technique for sharpening and smoothing images. Bilateral filter is only an noise reducing smoothing and edge-preserving filter where as the adaptive bilateral filter improve the accuracy level of detection by smoothing edge , preserving and noise reducing. It provides much smooth and noise free images as output.

$$it[m_0,n_0;m,n]=\begin{cases} w_{m0,n0}^{-1} \exp\left(-\frac{(m-m0)^2+(n-n0)^2}{2\sigma_d^2}\right)\exp\left(-\frac{(g[m,n]-g[m0,n0]-c(m0,n0))^2}{2\sigma_g^2}\right) & [m,n]\in\Omega_{m0,n0} \\ 0, & \end{cases}$$

where $[m0, n0]$ is the center pixel of the window,

$$\Omega_{m0,n0}=([m,n]:[m,n]\in[m0-N,m0+N]\times[n0-N,n0+N]),$$

4.2 Line segment detection

ED lines algorithm is used to detect the lines in all the images (ED Lines algorithm is a linear time line part detector which draws edge by using clean and contiguous chain of edge pixels).

4.3 Perceptual grouping

At the last step perceptual grouping is used for final extraction of buildings from satellite image. Perceptual grouping is the process of determining that which regions or part of the visual sight belong together. It identifies small region as the parts of higher order perceptual units. It is a widely used and specialized technique for polygon building extraction. It is used to set up a relationship between lower- level image primitives and higher level object (intersections , line segment and closed building boundaries).Perceptual grouping analyze the process in which enables our visual system to determin that what regions and part of an image belong together as objects.

5. SIMULATION RESULTS AND DISCUSSION

In this study to evaluate the performance of the our proposed method, four 512 X 512 pixel Quickbird Satellite images are studied. The proposed method run on PC with an AMD Quad core 2.8 Ghz CPU with 6 GB RAM. Figures 2-5 show the original images of landcover taken by Quickbird Satellite .First image contains only five houses, second contains 20 houses of different sizes, third one contains 17 houses with complex structure and fourth image contains 72 houses.

Figure-2Testimage1

Figure 3 Test image 2

ISSN (Online) 2394-2320

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Figure 4 Test image 3

Figure - 5 Test image 4

5.1 Preprocessing of input images and Comparison of BF and ABF

Adaptive bilateral filter and histogram equalizer are used to preprocess these images to reduce noise and preserve edges in the image. Output image of adaptive bilateral filter is compare to the output image of bilateral filter. As indicated in figure (5), images of first column form left shows the original images, images of second column from left shows the histogram equalized images of original images, images of third column from left shows the output images of adaptive bilateral filter and images of fourth column from left shows the output images of bilateral filter. As shown in images of second column from left, the contrasts of images are increased by the histogram equalization. Images of third column from left and images of fourth column from left show that the adaptive bilateral filter reduces noise and preserve edges in the images and PSNR is less than the output image of bilateral filter.

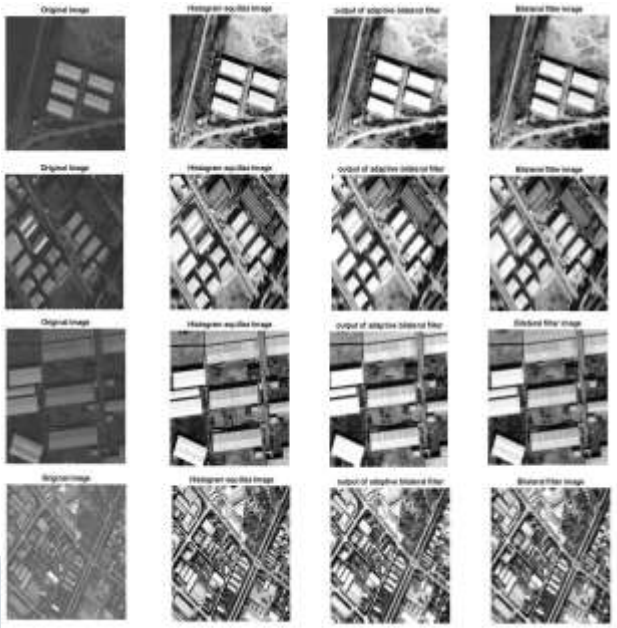

figure - 5 Comparison of bilateral filter and adaptive bilateral filter EDLSD

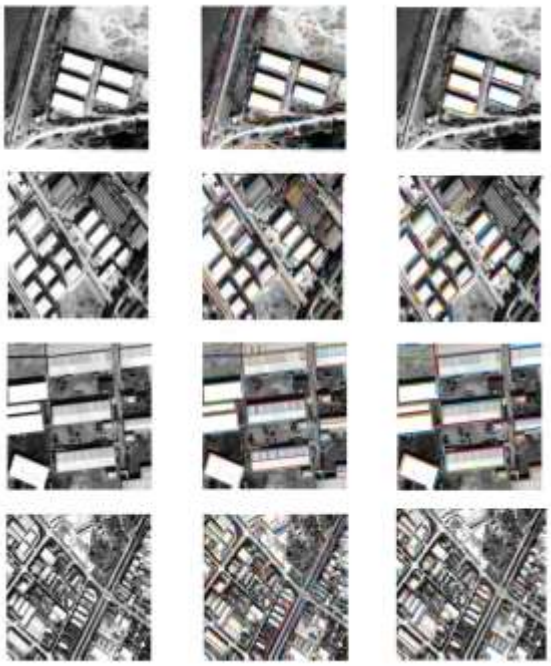

figure - 6 Comparison of original images, Histogram equalized images, ABF images and images of bilateral filter

ISSN (Online) 2394-2320

International Journal of Engineering Research in Computer Science and Engineering (IJERCSE)
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As shown in figure (5), images of first column form left shows shows the original images, images of second column from left shows the histogram equalized images of original images, images of third column from left shows the output images of adaptive bilateral filter and images of fourth column from left shows the output images of bilateral filter.As shown in left middle figure, the contrasts of images are increased by the histogram equalization. Right middle and right figures show that the adaptive bilateral filter reduces noise and preserve edges in the images and PSNR (Peak Signal to Noise Ratio (PSNR) is a error metrics used to compare image comparison quality) is less than the output image of bilateral filter. Table 1 shows the PSNR values of all images after filtering by adaptive bilateral filter and bilateral filter. From Table 3, it is clear that the PSNR of image is reduced by one-third (approx) by adaptive filter compare to bilateral filter

Image	**Adaptive bilateral filter**	**Bilateral filter**
Image a.	107.9583	377.6041
Image b.	108.0719	377.2169
Image c.	108.1657	377.7649
Image d.	107.9883	375.3711

Table 1. Comparison of bilateral filter and ABF (PSNR values of all image

EDlines algorithm is used to detect the lines in all the images. final extraction of buildings in image perceptional grouping is done. In figure (6) , middle image shows the EDlines result of output of image of adaptive bilateral filter and right image presents the final extraction. For final extraction of buildings in image perceptional grouping (Perceptual grouping is used for final extraction of building from satellite images. Perceptual grouping is a process of determining that which regions and parts of the visual scene belong together. it identifies small region as the parts of higher order visual scene such as a specific objects or patterns.It is a widely used and specialized tool for structural building boundary extraction. It is used to set up relationship between lower- level image regions and parts and higher level object . In figure-6, middle image shows the EDlines result of output of image of adaptive bilateral filter and right image presents the final extraction.

5.2 Time efficiency and accuracy measurement of ABF

Time efficiency of proposed method is shown in Table - 2 and accuracy assessment is shown in Table - 3
As shown in Table - 2, the EDlines takes 0.0443s, 0.0414s, 0.0477s and 0.0414s for image (A), (B), (C) and (D) respectively and we get 143, 271, 171 and 318 lines for each image. The assessment of accuracy of proposed method is demonstrated in Table - 2. In table - 3, NFLP, NTRP, NFLN represents the number of false +ve, number of true +ve, and number of false -ve respectively. Based on these parameters, false negative rate (FNGR) and detection rate (DTR) are computed as following.

$$DTR = \frac{N_{TRP}}{N_{TRP} + N_{FLP}} \quad FNGR = \frac{N_{FLN}}{N_{TRP} + N_{FLN}}$$

Table - 2 Time efficiency measurement of proposed method

Image ID	***(A)***	***(B)***	***(C)***	***(D)***
EDlines (s)	0.0443	0.0414	0.0477	0.0414
Number of lines	143	271	171	318

Table - 3 Accuracy measurement of proposed method

Total number of Building	Number of TRP	Number of FLP	Number of FLN	DTR	FNGR
104	90	12	12	88.24	11.76

As shown in Table - 3, building can be detected with an accuracy of 88.24. Though, due to various background interference and other factors, there are 12 wrong detected building and 12 false detected buildings, with false –ve rate of 11.76% for total 104 polygonal buildings in four different images.

6. CONCLUSION

In this study, a new method is presented to extract the building automatically for VHR satellite imagery based on EDlines, a line detector and a specialized tool called perceptual grouping for structural building boundary

extraction. In starting phase of the proposed method, Histogram equilibrium increases the contrast of the image and adaptive bilateral filter surprisingly improve the detection accuracy by noise reducing , edge preserving and smoothing Adaptive Bilateral filter is better than bilateral filter for the edge preserving smoothing. PSNR value is reduce by almost one fourth by adaptive bilateral filter compared to bilateral filter. After that at Second stage, through the combination of EDlines, algorithm for line detection based on Edge drawing and perceptual contour line analysis we are able to achieve more promising and more accurate experimental results. Hence the proposed method for building extraction gets fine results with overall accuracy of 88.24%, which is accurate enough for further image understanding building boundary detection and identification of target in real time environment. This algorithm can be used in urban planning and urban monitoring to observe proper implementation of urban plan and policies.

7. FUTURE WORK

As it has been proved from experimental result and comparison that the proposed method for building boundary detection and extraction provides much accurate result than earlier. But still it has some aspect to work like the roof of the building may be composed of different surfer's material with different reflection properties.

REFERENCES

[1] G. Vosselman, "Cartographic Feature Extraction."Institute for Photogram metrie and Landesver messungsamt NRW Bonn, Germany, 1-10. Accessed 10/9/2006, 1998.

[2] Gruen, and H. Li, "Road extraction from aerial and satellite images by dynamic programming", ISPRS Journal of Photogrammetry and Remote Sensing, 50(4), 11-20, 1995.

[3] Tao, M. A. Chapman, and f. Masters, "Semiautomatic object pointing using multi-image matching for mobile mapping", ACSM/ASPRS Annual convention, 265-274,December 2000

[4] S. Noronha and R. Nevatia “Detection and modelling of buildings from multiple aerial images”, IEEE Transactions on pattern analysis and machine intelligence, vol.23, no.5,2001

[5] M. Fradkin, H. Maitre and M. Roux “Building detection from multiple aerial images in dense urban areas", Computer vision and image understanding, Vol 82, 2001.

[6] M. Cord, M. Jordan and J. Cocquerez “Accurate building structure recovery from high resolution aerial imagery", Computer vision and image understanding, Vol 82, 2001.

[7] Fraser, C. S., Baltsavias, E., and Gruen, "A. Processing of IKONOS imagery for sub metre 3D positioning and building extraction" , ISPRS Journal of Photogrammetry and Remote Sensing, 56(3), 177-194, 2002.

[8] T.Guo and Y. Yasuoka, “Snake-based approach for building extraction from high-resolution satellite images and height data in urban areas”, Proceedings of 23rdAsian Conference on Remote Sensing, 2002.

[9] H. Rüther, H. M. Martine and E.G. Mtalo “Application of snakes and dynamic programming optimization echnique in modelling of buildings in informal settlement areas” , ISPRS Journal of Photogrammetric & Remote Sensing, Vol. 56, 2002.

[10] D. S. Lee, J. Shan, and J. S. Bethel, "Class-Guided Building Extraction from IKONOS

imagery",Photogrammetric Engineering and Remote Sensing, 69(2), pp.143-150, 2003.

[11] A.K. Shackelford, and C. H. Davis, "A Combined Fuzzy Pixel-Based and Object-Based Approach for Classification of High Resolution Multispectral Data over Urban Areas ",IEEE Transactions on Geosciences and Remote Sensing, Vol.41, 2003.

[12] J. A. Benediktsson, M. Pesaresi, and K. Arnason, "Classification and Feature Extraction for Remote Sensing Images from Urban Areas Based on Morphological Transformations.",IEEE Transactions on Geosciences and Remote Sensing, 41(9), pp. 1940-1949, 2003.

[13] B. P. Baltsavias, "Object Extraction and Revision by image Analysis Using Existing Geodata and Knowledge Current Status and Steps towards Operational Systems.",ISPRS Journal of Photogrammetry and Remote Sensing, 58, pp.129-151, 200

[14] C. Brenner, "Building Reconstruction from Images and Laser Scanning.", International Journal of Applied Earth Observation and Geoinformation, 6, pp. 187-198, 2005.

[15] J.Hu, S. You, U. Neumann "Integrating LiDAR, aerial image and ground images for complete urban building modelling",Proceedings of the Third International Symposium on 3D Data Processing, Visualization, and Transmission, 2006.

[16] F.O. Chikomo, J.P. Mills and S.L. Barr "An integrated approach to level of detail building extraction using airborne lidar and optical imagery",Photogrammetric Image Analysis, Munich Germany, 2007.

[17] D. Koc San , and M. Turker "Building extraction from high resolution satellite images using Hough transform " ,International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVIII, Part 8,Kyoto Japan, 2010.

[18] D. Girish Kumar, M. Padmaja" A novel image processing technique for counting the number of trees in a satellite image " ,Scholars Research Library, European Journal of Applied Engineering and Scientific Research, 1 (4):151-15, 9, and 2012.

[19] M.Kumar, R.K. singh Y.V.N. Kishnamurthy" Road Network Extraction from high resolution Multispectral Satellite Imagery Based on Object Oriented Techniques", Remote Sensing and Spatial Information Sciences, Volume II-8, 2014 ISPRS Technical Commission VIII Symposium, 09 – 12, Hyderabad, India, December 2014

[20] Zhixin Qi, Anthony Gar-On Yeh, Xia Li, Shi Xian, Xiaohu Zhang. "Monthly short-term detection of land development using RADARSAT-2 polarimetric SAR imagery",Remote Sensing of Environment 164 (2015) 179–196.

[21] Abdelali Benali , Hakima Dermeche , Sabrina Belhadj, Akram Adnane,Amar Hanifi Elhachemi "Building extraction of very high spatial resolution satellite images",[12] 978-1-4799-3824-7/14/$31.00,2014 IEEE

[22] Neeti Shrivastava , Praveen Kumar Rai ,"An object based building extraction method and classification using high resolution remote

sensing data",Forum geographic Volume XIV, Issue pp. 14-21(8) ,1 June 2015.

[23] Jun Wang, Qiming Qin, Li Chen, Xin Ye, Xuebin Qin,Jianhua Wang, Chao Chen ”Automatic Building Extraction from very high resolution satellite imagery using line segment detector”,Institute of Remote Sensing and Geographic Information System Peking University, Beijing,100871,2013China.

[24] Buyue Zhang, Member, IEEE, and Jan P. Allebach, Fellow, IEEE ”Adaptive Bilateral Filter for Sharpness Enhancement and Noise Removal ” IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL.17, NO. 5, MAY 2008.

[25] Cuneyt Akinlar and Cihan Topal” Edlines: Real-Time Line Segment Detection By Edge Drawing (Ed)” 2011 18th IEEE International Conference on Image Processing978-1-4577-1303-3/11/$26.00 ©2011 IEEE 2837.

[26] Cihan Topal, Cüneyt Akınlar, Yakup Genç, ” Edge Drawing: A Heuristic Approach to Robust Real-Time Edge Detection” 2010 International Conference on Pattern Recognition.