Satellite Imagery Cadastral Features Extractions using Image Processing Algorithms: A Viable Option for Cadastral Science

Usman Babawuro, Zou Beiji
School of Information Science and Engineering, Department of Computer Science, Central South University, Changsha, Hunan, 410083, PR China.

Abstract
Satellite images are used for feature extraction among other functions. They are used to extract linear features, like roads, etc. These linear features extractions are important operations in computer vision. Computer vision has varied applications in photogrammetric, hydrographic, cartographic and remote sensing tasks. The extraction of linear features or boundaries defining the extents of lands, land covers features are equally important in Cadastral Surveying. Cadastral Surveying is the cornerstone of any Cadastral System. A two dimensional cadastral plan is a model which represents both the cadastral and geometrical information of a two dimensional labeled Image.

This paper aims at using and widening the concepts of high resolution Satellite imagery data for extracting representations of cadastral boundaries using image processing algorithms, hence minimizing the human interventions. The Satellite imagery is firstly rectified hence establishing the satellite imagery in the correct orientation and spatial location for further analysis. We, then employ the much available Satellite imagery to extract the relevant cadastral features using computer vision and image processing algorithms. We evaluate the potential of using high resolution Satellite imagery to achieve Cadastral goals of boundary detection and extraction of farmlands using image processing algorithms. This method proves effective as it minimizes the human demerits associated with the Cadastral surveying method, hence providing another perspective of achieving cadastral goals as emphasized by the UN cadastral vision. Finally, as Cadastral science continues to look to the future, this research aimed at the analysis and getting insights into the characteristics and potential role of computer vision algorithms using high resolution satellite imagery for better digital Cadastre that would provide improved socio economic development.

Keywords: *Geo-rectification, Cadastral Surveying, Morphological operation, Hough Transform*

1. Introduction

Computer vision is concerned with the development of systems that interpret the contents of natural scenes. It begins with the process of detecting and locating some features in the input image. The degree to which a computer extracts meaningful information from the image is the most powerful key to the advancement of intelligent image understanding systems [1]. The ultimate goal of computer vision is to use computers to emulate human vision, through learning, making inferences and taking actions based on visual inputs [2]. The true power of the human mind is clearly revealed by its ability to easily perform visual interpretation tasks that are exceedingly difficult for computers [3]. Yet the desire to use computers for these tasks persists because of its ability to process vast amount of data effectively and efficiently. Image processing is a rapidly growing area of computer science. Its growth has been fueled by technological advancements in digital imaging, computer processors and mass storage devices [4]. It is primarily concerned with the extraction of useful information from images of different kinds using different algorithms like those of image enhancement and object detection [5]. Image processing algorithms could be classified at three levels. At the lowest level are those techniques which directly deal with the raw, possibly, noisy pixel values, with de-noising and edge detection algorithms being typical ones. In the middle are algorithms which utilize low level results for further means, such as segmentation and edge linking. At the highest level are those methods that attempt to extract semantic meaning or certain features from the information provided by the lower levels, for instance, handwriting recognition or geometric feature extraction [4]. In computer vision, a feature is defined as a function of one or more measurements, each of which specifies some quantifiable property of an object, and is computed such that it quantifies some significant characteristics of that object [1]. They are classified as pixel, local, global and domain specific features. On the other hand, all features are loosely classified into low-level features and high-level features. Low-level features can be extracted directly from the original images, whereas high-level feature are extracted based on low-level features. Satellite images are either panchromatic, multispectral, hyper spectral or ultra spectral. The multispectral images have higher spatial resolutions while the panchromatic ones relatively have lower spatial resolutions but they are rich in spectral information [6]. Research on image processing using multi resolution satellite imageries have attracted computer vision and image processing communities since most environmental and socio-economic needs are based on these imageries [7, 8, 9]. Additionally, satellite imageries, contain vast remotely sensed data, which offers a huge source of data for studying spatial and temporal changes of the environment. It contains both spectral and spatial information [10]. The digital analysis of satellite imagery data has become an important component of a wide range of land studies [11]. With the advent of multi-spectral and high resolution satellite imagery, more information that is processed and analyzed to generate better representations of the features of the earth are available [9, 12]. Before, due to the low resolution of the former generation of satellite imagery, the use of satellite data in the surveying or geomatics field has been very limited, but this has gradually changed with the introduction of high-resolution satellite imagery amongst other geomatic or geo-information technologies [11]. Among the Surveying applications is the Cadastral application of high resolution satellite imageries as shown in Fig1. The few investigative cadastral work conducted using high resolution satellite imagery have shown that a spatial resolution of 2m or better is required to support most cadastral applications [12]. This threshold of spatial resolution is realized with the launch of systems offering the potential of up to <1m panchromatic and <4m multi-spectral spatial resolutions [11]. This encouraged us to do more research in this direction. Feature extraction in Satellite imagery is an important operation in computer vision. It has many applications, especially in geomatics or surveying, and hydrography [13], photogrammetric and remote sensing tasks. It is used to extract linear features, like roads, from satellite or low resolution aerial imagery [14]. For some of these mapping tasks, the extraction of boundaries that define lands or other features can be quite important in Cadastral Surveying. [15], gives an detailed overview of cadastral surveying. Cadastral plan is technically an extension of 2 dimensional images. The 2D property and the planimetric nature of the satellite imagery allow an efficient implementation of the main topological and geometrical operations of image processing algorithms, especially image segmentation using high resolution satellite imagery [16].

Geo referenced high-resolution satellite image is used for acquisition of topographic information, navigation and visualization for various environmental studies [12, 17], such imagery could as well be used as a topologic map. Geo referenced high resolution satellite imagery is used in a number of applications, that include reconnaissance survey, identification and classification of spatial features for geographical uses, creation of mapping [12] products for military and civil applications, for the inventory, monitoring, and management of natural resources, surveillance, evaluation of environmental damages, monitoring of land uses for physical planning, urban and town planning, growth regulation, soil assessment, etc. Satellite Imagery offers as part of its merits, imperative coverage, mapping and classification of land-cover features, namely vegetation, land cover, soil, water, coastline [13], forests, etc. The principal application of satellite imagery data is to create a classification map of the identifiable or meaningful features or classes of land cover types in sceneries. So, the principal product is a thematic map with themes like land uses, land cover types, geology, vegetation types, etc. Some of the major strengths of high resolution satellite image, as a source of information for Cadastral survey high geometrical resolution, multispectral capabilities, radiometric sensitivity, good positional accuracy, revisit capabilities and larger image size. More research is needed as stated by [18, 19] to explore these potentials as such our research is tailored towards this direction. So the focus of this research is an attempt to provide an alternative solution using computer vision approach. The research aims at widening the concepts of using high resolution satellite imagery data for extracting representations of cadastral boundaries with minimum human intervention. We, employ the much available Satellite imagery to extract the relevant cadastral features, farmlands, using computer vision and image processing algorithms. We evaluate the potential of using high resolution Satellite imagery to achieve Cadastral goals of boundary detection through reduced time, cost and human effort, hence having some crucial improvements for better and faster digitized Cadastral decisions making process using computer vision and satellite image processing algorithms.

The paper is structured as follows. Chapter 2 covers the related works, while chapter 3 contains the implementation. The discussions of the research are contained in Chapter 4, whereas chapter 5 concludes with conclusion and future works.

2. Related Works

Here we review the existing works in the field of Satellite imagery processing focusing attention on, feature extraction and boundary detection.

2.1 Feature Extraction and Boundary Detection

Satellite imagery feature extraction according to H. Liu, et al. [20] was done using image segmentation, based on a locally adaptive thresholding technique. They extracted coastline by using Levenberg-Marquardt method and the Canny edge detector to speed up the convergence of iterative Gaussian curve fitting process and to improve the accuracy of the bimodal Gaussian parameters. They didn't carry out imagery rectification as such feature boundary orientation could not be used for further analysis. A.A.Vakilian et al. [21] used Level Set Method (LSM) and Snakes Method (SM) to determine objects location and boundaries. In their work, a new algorithm for image processing of the weak gradient features was developed to improve the overall image boundary detection system. This algorithm was based on the active contour model in conjunction with LSM to enhance images detection. M. Boldischar et al. [22] presented feature extraction from the point of view of automated fingerprint identification system. T. Gustavsson et al. [23] implemented and compared four different boundary detection algorithms for quantitative measurements of the human artery. Hyper spectral image feature extraction based on generalized discriminant analysis was presented by G. Yang et al. [24]. H. G. Momm et al. [25] investigated the use of genetic programming to aid the feature extraction process from high-resolution satellite imagery. O. Sharmay et al. [9] described a method where the boundary extraction algorithm converts detected image features into connected sets of vectors that are topologically equivalent to the segmented objects. G. Damiand et al. [16] define the two dimensional, 2D, topological map, as a model which represents both topological and geometrical information of a two dimensional labeled image. They assumed that the model is minimal, complete and unique, so they use it to define efficient image processing algorithms.

In our work, we also consider a cadastral plan to be a 2-D 'image' as such features are extracted using efficient image processing algorithms. Our consideration is based on the fact that cadastral surveying employs a plane surveying techniques which is also 2 dimensional with boundary edges as straight lines. With this in mind and the application of georectification process, we processed the high resolution satellite imagery for the purpose of cadastral features detection and extraction. Technically, we apply morphological operations to the Canny edged geo rectified satellite image in order to segment the field boundaries, separating the farmland from all others. Prior to these, the image is dimensionally reduced to get rid of some redundant data. The imagery is then treated for boundary detection of the fields for cadastral purposes. Then we applied a global edge linking algorithms Hough transform to detect and link edges.

3. Implementation

The high resolution Satellite imagery is first georectified to have a planar orientation that would make it suitable for cadastral quantitative analysis. For details on Geo rectification of Satellite imagery refer to U. Babawuro et al. [26]. Then because of the huge redundant information embedded therein, image dimensionality reduction is necessary in order to remove certain unwanted information and still have the much needed ones for further processing with less computational fatigue as a great merit. This made us to apply Discrete Wavelet Transform (DWT) to the georectified satellite imagery so that we could be left with less and more useful information for our purpose. Since computational image quality metrics are designed to predict contrast detection thresholds [27], the quality of the imagery is also tested using image metrics to determine its quality both qualitatively and quantitatively. These metrics are useful in image quality evaluation as they are used to predict the visibility of image distortions introduced by imaging devices and processing methods. For details on Satellite imagery quality evaluation for quantitative cadastral analysis, refer to B. Usman et al. [6].To segment the image, the gray imagery of the original image is subjected to Canny and Sobel edge detection methods to make a practical choice. From the outputs, Sobel edged image contained a lot of edge discontinuities as such it is discontinued, whereas that of Canny method contained smooth and continuous edges. To further extract the object boundaries, which are the farmland boundaries, from the Canny edged detected image, morphological operations, dilation and erosion are applied. Equal number of dilation and erosion was applied to the imagery using a 2x2 structural element, which provides an image with black and white patches. Then a 4x4 structural element is applied separately. At this stage, the entire farmlands are segmented and depicted as black objects against white background. To delineate the cadastral boundary edges, Hough Transform is applied. From the result, we noted that Hough transform, detected the edges as straight lines, though there are few omissions. Very clear thin boundaries of the segmented black farmland-objects are obtained against a black background with the application of Canny method to the image again.

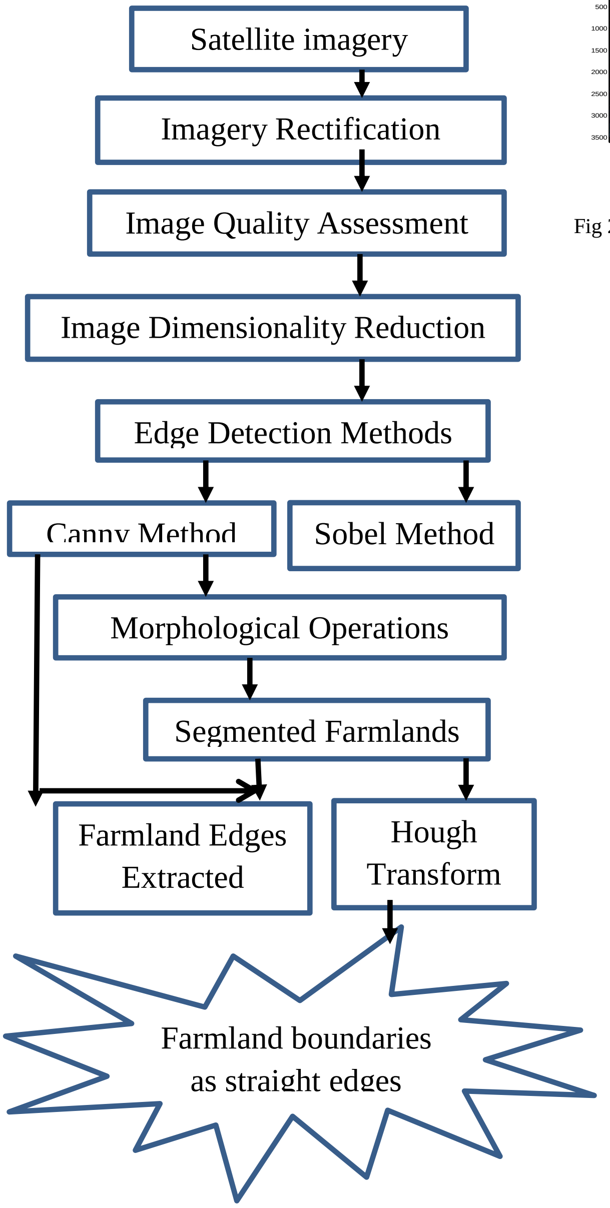

Fig 1, Flow Chart of the Farmlands Extraction

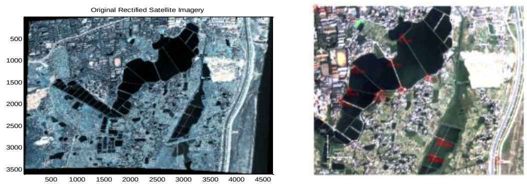

Fig 2 shows the Original image and the region of interest for rectification

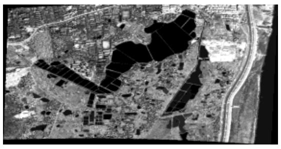

Fig. 3 Shows the Gray Image

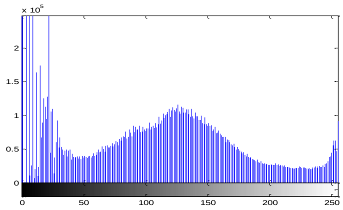

Fig 4 Shows the Histogram of the Imagery

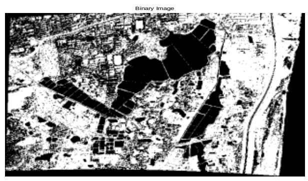

Fig. 5 Shows the Binary Image of the original Image

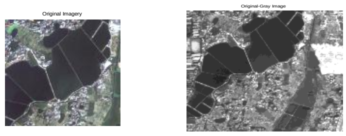

Fig. 6 Both Original and Gray image for edge detection

3.1 Satellite Imagery dataset

The Satellite imagery used in this study is a high resolution Quick Bird Satellite imagery with a 2.4m resolution acquired in 2005, over a relatively flat landscape in Changsha city, Hunan province in the South Central region of PR China. This, imagery, 593X533, has a total number of pixel vectors, N, 316069. The imagery is composed of a residential matrix textured with farmland patches of varying sizes and shapes which are excellent features with cadastral values. The three land-use classes dominating the scene are residential, agriculture and commercial.

3.2 Dimensionality Reduction using Wavelet Decomposition

Using the three level discrete wavelet transform, the input image is decomposed into two frequency coefficients, the approximation coefficients as the low frequency part and the detail coefficients as the high frequency part. This is called wavelet decomposition. With higher level decompositions, multi resolution representation of the image is achieved. Fig.7 shows the wavelet decomposition of the satellite imagery. The other images are the decomposition at higher levels as we can see from the right images

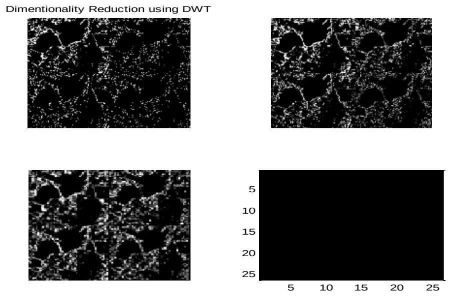

Fig 7 Imagery dimensionality Reduction

3.3 Image Segmentation

[9], states that edge detection produce global edges in an image. This means that there is no object definition attached to the edges. It is required to somehow define the objects first and then obtain edges from them. This can be achieved by using image segmentation. Segmentation refers to the process of partitioning a digital image into multiple regions, sets of pixels. These regions may be later associated with ground cover type or land use, but the segmentation process simply gives generic labels. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries in images. The regions consist of groupings of multispectral image pixels that have similar data feature values. These data feature values may be the multispectral data values and/or they may be derived features such as band ratios or textural features [8]. It means the quality of image processing heavily depends on the quality of segmentation process. In this work, we applied Canny edge detector to segment the imagery. By using detector, gradient values are obtained. If global threshold value is used on that gradient image, the gradient values along the potential edge will be lost. In order to avoid this effect a local threshold in the area of interest is applied [28]. Image segmentation has two objectives. The first is to decompose an image into parts; the second is to perform a change of representation. Pixels of an image must be organized into higher-level units that are either more meaningful or more efficient for further analysis. Segmentation should stop when objects of interest have been isolated. Image segmentation processes are divided into two groups: discontinuity and similarity groups as shown in fig 8

Segmentation → Similarity → Thresholding → Region Growing → Region Splitting → Region Merging

Segmentation ↓ Discontinuity → Abrupt changes in Gray levels → Detection of Points, Lines and Edges

Fig 8 Shows types of Segmentation

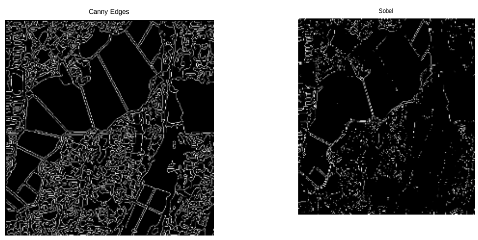

Fig.9 Shows Canny and Sobel edges

3.4 Morphological Operations using Satellite Imagery

Morphological operations are excellent mathematical tools for filtering images. They are used to remove noise and to as well provide shape and boundary description of objects within an image. Its main operations are dilation and erosion. Before applying this operation, images are represented by a set of points or point's sets. Dilation is a kind of vector addition while erosion is a kind of vector subtraction. Morphological opening and closing tends to smooth the contours of objects. Unlike opening, closing joins narrow breaks, fills long thin gulfs, and holes smaller than the size of the structural element [31].

3.4.1 Dilation and Erosion operation

Conducting the dilation and erosion operations on the gray satellite imagery with a 5x5 structural element gives the following results: fig 10 and fig11. Despite, the gray image is the same for the two morphological operations; the dilated image appears thicker in boundary and having better contrast, fig10, vis-à-vis the eroded image that has relatively thinner boundary and with less contrast, so much darker, fig11. This shows that dilation adds pixels to boundaries making them thicker whereas erosion removes pixel from boundaries, making them thinner.

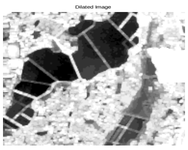

Fig10 shows dilated image using a 5x5 strel element

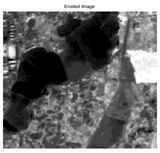

Fig11 shows eroded image using a 5x5 strel element

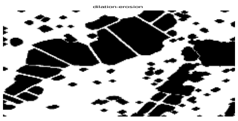

Fig12 Shows 3x times dilation followed by 3x times erosion (2x2 structural elements)

Fig.13 Shows 3x times dilation followed by 3x times erosion (4x4 structural elements)

This kind of operation is then applied to the edged imagery using two different structural elements. When the satellite imagery is operated using morphological operations, the dilation and erosion operation, three times using 2x2 structural elements, displayed a hopeful image but with black patches as is seen in Fig.12. When conducting such operations, the structuring element should be large enough to remove the lines when you erode the image, but not large enough to remove the object needed. It should consist of all 1's, so that it removes everything but large contiguous patches of foreground pixels [29]. So we then repeat the process using a larger 4x4 structural elements. This resulted in a cleaner image showing all the field boundaries as black objects against a white background, Fig13. We successfully applied the morphological closing operations on the gray image to extract the field features as shown in fig 13.

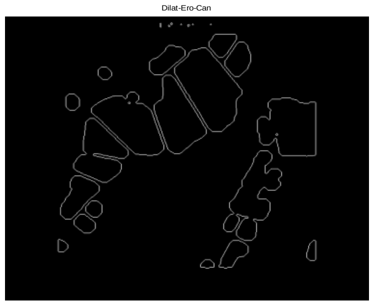

Fig14 shows the thin edges of the farmland's boundaries after the edge and morphological operations

3.5 Hough transform and Satellite Imagery

The Hough Transform is considered a very powerful tool in edge linking. Its main advantages are its insensitivity to noise and its capability to extract lines even in areas with pixel absence, pixel gaps. The standard Hough Transform proposed by Duda and Hart in 1972, is widely applied for line extraction in natural scenes, while some of its modifications have been adjusted for extraction purposes [30]. The classical Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses, etc. It requires that the desired features be specified in some parametric form.

3.5.1 Straight line detection using HT

Let us consider all the possible lines which can go through an image point (s, t): t = m s + c. The parameters of all these lines form a straight line in the parameter space m, c. Both m and c can attain any value from $-\infty$ to $+\infty$. To parameterize the line is [32]:
$r = x \cos\theta + y \sin\theta$ as given in equation (1)
where, $x = a + r\cos\theta$, $y = b + r\sin\theta$.

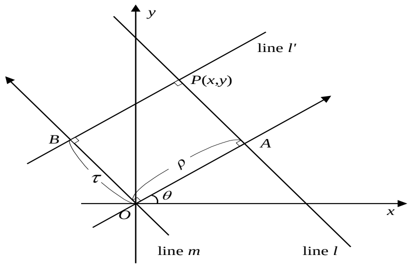

Fig.15 Hough transform for line detection

Hough transform for line detection yields an equation of a line for line l shown Fig15

$$\rho = x\cos\theta + y\sin\theta \quad (1)$$

where ρ is the normal distance of the line l from the origin O passing through a feature point P(x,y) shown in Fig.15 (or equivalently, the distance of the line OA that is normal to the line l). θ represents the angle between the x-axis and the line OA, with 0≤θ<2π and $-\rho_{\max} \le \rho \le \rho_{\max}$. Since ρ is reversed whenever θ=2π, 0≤θ<π and $-\rho_{\max} \le \rho \le \rho_{\max}$ are assumed, $\rho_{\max} = K/\sqrt{2}$ is measured from the center O of the image K×K. Note that, the point A is the most nearest point from the origin, among all the points on line l. There are an infinite number of lines which pass through a fixed pixel in an image plane, with each line represented by two parameters θ and ρ. Thus a single pixel in the image plane is mapped into an infinite number of points in the θ-ρ line parameter space. Detection of the dominant line in the image plane is achieved by finding a peak in the accumulators of parameter arrays. Each of the straight lines passing through a fixed point in an image plane is mapped into a large number of discrete points (θn, ρmn), $0 \le n \le N$, $-M \le m \le M$, on a periodic sinusoidal curve in the θ-ρ parameter space, where N and (2M+1) represent the total numbers of quantized angle and distance cells, respectively. Note that θn is the nth uniformly quantized angle of θ in the bounded parameter space, for reduction of the computational complexity, and that ρmn denotes the quantized distance of ρn that corresponds to θn in Eq.1 . Moreover, using Satellite Imagery we got the following results as shown in Fig16 and Fig17.

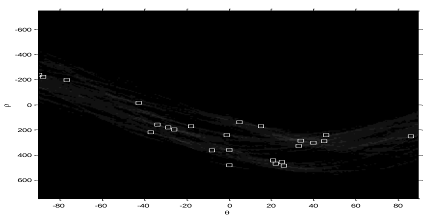

Fig.16 3.15 shows the Hough Transform

Fig 17 3.16 Shows the Hough transform delineating the farmlands boundaries.

4. Discussions

When we dilate the imagery with any of the structural elements, the farmlands being the image objects expands but when the opposite operation of erosion, the same image shrinks as compensation. With these operations, the farmland boundaries are detected and clearly extracted, Fig.13 and Fig14. This will help us to find other geometric parameters of the farmlands in future work. However as [1] noted, HT has the following demerits. Coarse resolution, lack of locality, expensive to implement, especially for high resolution and has trouble in finding short segments in images; there are many opportunities and challenges in using HT for extracting cadastral features. It is an area of growing importance locally and globally. More attention from the image processing community needs to be directed toward studying and extracting cadastral features as a result of their socio economic values. In our work, though boundaries of the lands are extracted and detected clearly, there are some boundaries that are not well captured.

5. Conclusions

Currently, high-resolution satellite image processing amongst other geo-information technologies is proving useful for cadastral surveys. This research looks at the possibility of integrating machine vision technology into digital cadastral surveying. The study is based on the hypothesis that image processing algorithms together with high resolution satellite imagery could be used to determine the extents of cadastral features for the execution of statutory cadastral functions for more effective development. The results proves that the proposed approach effectively extracts the objects of interest from the high resolution satellite imagery using canny and morphological operations to extract the farmland object boundaries. Hough Transform, an excellent linking tool, is applied to detect the straight edge of the boundaries for onward quantitative analysis. It is noted that the processing of Satellite imagery using the relevant image processing algorithms provides a powerful visual and management tool for a more comprehensive cadastral land information extraction. This makes Cadastral Surveying not only be in tune with its ever growing and evolving societal demands but also makes it maintains its sustainability within the society.

5.1 Further Works

It would be interesting, as part of future research to extract more information about each of the extracted object. We can compute the following parameters using object geometry perimeter, area, caliper, roundness, aspect ratio, compactness, extent, form factor, and equivalent diameter. In addition, with further improvement, the features extracted may be used for urban planning, ground water estimation, GIS mapping etc.

Acknowledgment

This research work was supported by the National Research Foundation for Higher Education of China and the Kano University of Science and Technology, KUST, Wudil, Nigeria, through the Educational Trust Fund, ETF, Nigeria.

References

[1] B.J. Lei, E.A. Hendriks, M.J.T. Reinders, On Feature Extraction from Images, Technical report on inventory properties for MCCWS project, Information and Communication Theory Group TUDelft, June 01, 1999

[2] R.C Gonzalez, R.E Woods, Digital Image Processing, 3rd Edition, 2010

[3] M.A Schulze, Automatic determination of GIS boundaries from Satellite Imageries, Manaaki Whenua- Land Care Research, Grace field, Lower Hutt.

[4] T. Seemann, Digital Image Processing Local Segmentation, Monash University Australia, PhD Thesis, 2002

[5] D.V. Rao, S. Patil, N.A. Babu, V. Muthukumar, Implementation and Evaluation of Image Processing Algorithms on Reconfigurable Architecture using C-based Hardware Descriptive Languages, International Journal of Theoretical and Applied Computer Sciences Volume 1 Number 1pp.9–34(2006) http://www.gbspublisher.com/ijtacs.htm

[6] B. Usman, Z. Beiji, Satellite Imagery Quality Evaluation using Image Quality Metrics for Quantitative Cadastral Analysis, International Journal of Computer Applications in Engineering Sciences, vol I, Special Issue on AISC, 2011

[7] K. Perumal, R. Bhaskaran, Supervised Classification Performance of Multispectral Images, Journal of Computing, Volume 2, Issue 2, 2010, Issn 2151-9617

[8] M. Toshniwal, Satellite Image Classification Using Neural Networks, Inter Conf; Sciences of Electronic, Technologies of Information and Telecommunications, 2005

[9] O. Sharmay, D. Miocz, F. Antony, Polygon feature extraction from satellite imagery based on Colour image segmentation and medial axis, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. xxxvii. 2008

[10] J. M. Bardsley, M. Wilde, C. Gotschalk, M.S. Lorang, MATLAB Software for Supervised Classification in Remotely Sensing and image processing , Journal of Statistical Software, Volume VV, Issue II

[11] J.D. Ondulo and W. Kalande, High Spatial Resolution Satellite Imagery For PID Improvement In Kenya, Shaping the Change, XXIII FIG Congress, 2006

[12] P.V. Radhadevi, V.Nagasubramanian, A. Mahapatra, S.S. Solanki, K. Sumanth, G. Varadan, Potential of High-Resolution Indian Remote Sensing Satellite Imagery for Large Scale Mapping, International Society for Photogrammetry and Remote Sensing, Volume xxxviii-5, 2009.

[13] H. Liu, K.C. Jezek, Automated Extraction of Coastline from Satellite Imagery by integrating Canny edge detection and locally adaptive thresholding Methods, Int. J. Remote sensing, vol. 25, no. 5, 937–958, 2004

[14] C. Steger, Extraction of Curved Lines from Images, Forschungsgruppe Bildverstehen (FG BV) Informatik IX, Technische Universitat Miinchen Orleansstr. 34,8 1667.

[15] I.P. Williamson, The Justification of Cadastral Systems in Developing Countries, Canadian Institute of Geomatics, Geomatica, Vol. 51, No. 1. Pp.21-36,1997. http://www.csdila.unimelb.edu.au/people/rteam/ianpub.html

[16] G. Damiand, Y. Bertrand, C. Fiorio, Topological Model for 2D Image Representation: Definition and Optimal Extraction Algorithm, Computer Vision and Image Understanding-93(2)-pp. 111-154

[17] K.H. Chi, S.S. Lee, Rectification Technique of High Resolution Images for Mountain Area, 8th International Conference on the Global Spatial data Infrastructure, GSDI-8, International Federation of Surveyors, FIG, 2005

[18] B. Usman, Design & Implementation of Systems for the Management of Land Related Information, MSc Thesis, Central South University, Changsha, Hunan, China, 2002

[19] B. Usman, 2010. "Cadastral Information System for Title Management in Nigeria". Pacific Journal of Science and Technology. 11(2):408-415,2010. www.akamaiuniversity.us/PJST.htm

[20] H. Liu, K. C. Jezek, Automated extraction of coastline from satellite imagery by Integrating Canny edge detection and locally adaptive thresholding Methods, Int. J. Remote sensing, vol. 25, no. 5, 937–958, 2004.

[21] A.A.Vakilian, K.A. Vakilian, A new satellite image segmentation enhancement Technique for weak image boundaries, Annals of Faculty Engineering Hunedoara, International Journal of Engineering, Tome XISSN 1584 – 2665, 2012.

[22] M. Boldischar, C.P. Moua, Edge Detection and Feature Extraction in Automated Fingerprint Identification Systems, University of Wisconsin.

[23] T. Gustavsson, R. Abu-Gharbieh, G. Hamarneh, Q. Liang, Implementation and Comparison of Four Different Boundary Detection algorithms for Quantitative Ultrasonic Measurements of the

Human Carotid Artery, IEEE Computers in Cardiology Vol 241997
[24] G. Yang, X. Yu, X. Zhou, Hyper spectral image feature extraction based on generalized discriminant analysis, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. xxxvii. 2008
[25] H. G. Momm, B. Gunter, G. Easson, Improved Feature Extraction from High-Resolution Remotely Sensed Imagery using Object Geometry, SPIE 2010 Conf.
[26] U. Babawuro, Z. Beiji, X. Bing, "High Resolution Satellite Imagery Rectification Using Bi-linear Interpolation Method for Geometric Data Extraction," isdea, pp.1430-1434, 2012 Second International Conference on Intelligent System Design and Engineering Application, 2012. http://doi.ieeecomputersociety.org/10.1109/ISdea.2012.457 http://ieeexplore.ieee.org/xpl/articleDetails.jsp?partnum=6173478&searchProductType=IEEE Conferences
[27] K. Dong-O, P. Rae-Hong, New Image Quality Metric Using the Harris Response, Signal Processing Letters, IEEE, Volume: 16 Issue: 7, 616 – 619, 2009
[28] B. Chouhan et al., 2011, Iris Recognition System using canny edge detection for Biometric Identification, International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462 Vol. 3 No. 1
[29] Morphology Fundamentals, Dilation and Erosion, Matlab Help, Version 7.8.0.347, R2009a, 2009.
[30] V. Torre, T. Poggio, A.I Memo, On Edge Detection, Report by MIT Artificial Intelligence Laboratory, 1984
[31] R.C Gonzalez, R.E. Woods, S.L. Eddins, Digital Image Processing using Matlab, Pearson Education, Inc, Prince Hall, 2009
[32] M. Sharifi, M. Fathy, M. T. Mahmoudi, A Classified and Comparative Study of Edge Detection Algorithms, Proceedings of the International Conference on Information Technology: Coding and Computing (ITCC.02),

First Author: Usman Babawuro graduated from the Department of Surveying, Ahmadu Bello University, ABU, Zaria, Nigeria, with a Bachelor degree in Surveying in 1988. He then, obtained PGD and MSc in Computer Science and Technology from Central South University Changsha, China in 2002.

He worked as a Surveyor for some years, executing legal surveys in Nigeria. Then he joined the services of the Department of computer science, Kano University of Science and Technology, KUST, Wudil, Nigeria as an academic staff. To further his educational career, in 2009, he pursued a Doctoral Programme, at the School of Information Science and Engineering, Central South University, Changsha, China, where he worked with Image Processing and Virtual Reality Laboratory of the University for his research. During his stay in the lab, he published five papers in an international conference and at other international journals. He has already authored several papers in other journals and conferences. He is a professional member of both Nigerian Computer Society and Computer Registration Council of Nigeria. His research interest includes satellite image processing, pattern recognition and feature extraction.

Second Author: Zou Beiji

- Education Background

1978 – 1982 Zhejiang University, Hangzhou, China
BSC Computer Software.
1982 – 1984 Qinghua University, Beijing, China
MSc Computer Application.
1997 – 2001 Hunan University, Changsha, China
Ph.D. Control Theory and Engineering

- Research Experience

2002 – 2003 Qinghua University
Post Doctor
2003 – 2004 Griffith University, Australia.
Visiting Scholar.