Automated Extraction of Geospatial Features from Satellite Imagery: Computer Vision Oriented Plane Surveying

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

Abstract
The paper explores and assesses the potential uses of high resolution satellite imagery and digital image processing algorithms for the auto detection and extraction of geospatial features, farmlands, for the purpose of statutory plane surveying tasks. The satellite imagery was georectified to provide the planar surface necessary for morphometric assessments followed by integrated image processing algorithms. Precisely, Canny edge algorithm followed by morphological closing as well as Hough transform for extracting lines of features was used. The algorithms were tested using Quick bird satellite imagery and in all cases we obtained encouraging results. This shows that computer vision and image processing using high resolution satellite imagery could be used for cadastration purposes, where property boundaries are needed and used for compensation purposes and other statutory surveying functions. The error matrix of the delineated boundaries is estimated as equal to 73.33%.

Keywords: *Satellite imagery, Morphological operations, Hough Transform, Plane surveying, computer vision*

1. Introduction

Land has always been a source of living for humans, animals and other creatures. It has different forms and is often classified into types such as farmland, hunting land, pasture land, recreation lands etc. Farmland is of utmost importance to human beings and other living creatures. This has necessitated the importance of getting farmlands to be surveyed. Therefore, the importance of demarcating farmlands cannot be overemphasized because of the following reasons. The topography or gradient of the farmland can be determined and also absolute and relative positions of points on the farm and earth's surface can be determined. Farmland surveying can be used for environmental feasibility studies and it enables the farmer to make proper use of the land, among others. Since the results of surveying which are either in graphical or numerical form help to describe the characteristics and features of the various soil units, we can reliably say that farmland maps or soil map helps in planning and planting of crops. The inputs like labor, chemicals, seeds, fertilizers can be determined before actual farming starts and the yield or productivity of farmland can be projected as well. Farmland surveying helps to make proper use of resources available and also to project the maximum profit achievable. The Certificate of Occupancy (C. of O.) incorporating a cadastral plan which resulted from farmland surveying can be used as collateral for securing loan from financial institutions. In addition, through proper planning, it helps to prevent wastage of farmland and other inputs. Above all, with the C of O there is a guarantee of ownership of farmlands. Roads and other access routes within the farmlands can be planned and constructed with knowledge derived from the surveyed plans. To achieve all these, we simply need to delineate and demarcate farmlands boundaries or edges of farmlands as in digital image processing paradigm.

The foregoing are being achieved using the conventional land surveying techniques, namely plane surveying Fig 1. This technique is field oriented as such they are tedious and time consuming to say the least. It also encourages lack of transparency in the case of farmland compensation survey, as the surveyors physically associate and mingle with farmland owners. The conventional surveys cannot deliver the necessary information in a timely and cost-effective mode [1]. Plane table surveying is the technique mostly employed by field surveyors to delineate, demarcate and survey the boundaries of these farmlands for compensation surveys under the assumption that boundaries on the earth's surface are straight lines/edges for an area less than or about 250km^2 [2]. So within the stated limit, it assumes a 2D plane with straight edges. Based on this, farmland and boundary geometries are deduced for the execution of further statutory functions. Satellite remote sensing concerns the use of reflected or emitted electromagnetic radiation so as to obtain information about the Earth's features. With this broad definition, remote sensing includes a wide range of techniques to obtain information by devices ranging from simple devices to space borne multispectral imagery [3]. In the last decades, the imaging satellite sensors have acquired huge quantities of data with satellites collecting and transmitting down to the receiving stations in excess of 3 TB of data a day [4]. This encourages more applications of satellite date into various research fields including one of the oldest professions on earth, Surveying. The availability of this data, coupled with the computer capability necessary to analyze it, provides opportunities for environmental scholars and planners, particularly in the areas of land use, mapping and change detection [5]. Satellites images are used for military and civil applications particularly for surveillance, environmental monitoring, development and management [1]. The imageries are used for land cover classification in many cases. With the application of georectification correction, high resolution satellite imagery assumes a 2D plane surface that can be used for morphometric measurements of image features thereon. A more restrictive issue is the use of satellite imagery for detecting and mapping large-scale surveying features [3]. In this paper we attempt to use high spatial resolution satellite imagery for the detection and extraction of farmlands features using computer vision and image processing algorithms for use in compensation surveys instead of using the conventional plane surveying techniques, Fig 1, hence minimizing or eliminating some of the shortcomings of the surveying methods for a more sustainable digital Cadastral science, Fig 2. The organization of the paper is as follows: In Section 2 we explain the related work while the proposed methodology is detailed in Section 3. Results and discussion are presented in section 4. Finally section 5 draws the conclusion.

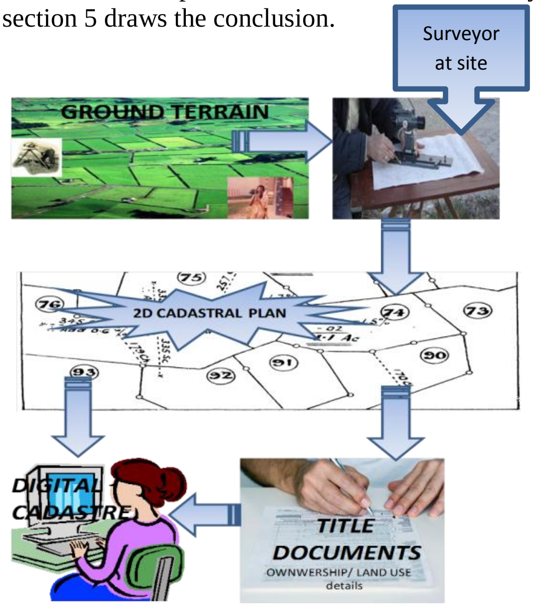

Fig.1Conventional Plane Surveying Concepts

2. Related Works

In the previous studies, S. A. Hsu [6] used satellite imagery to rapidly estimate coastal flooding induced by tropical cyclones to protect people from the damages inflicted by the cyclones. A. S. Mohammed et al. [1] used satellite imagery area-wide spatial information for city development and management, where the urban land cover classification is used to compute a spatial distribution of built-up densities within the city and to map homogeneous zones or structures of urban morphology. A.M. Montufo [3] assesses the potential use of satellite imagery and digital image processing for the detection and mapping of ancient land-use patterns for archeological purposes. He however used image processing software for the work. M. Rumanek et al.[7] used satellite imagery from another perspective by looking at the possibilities of high performance processing of satellite images using graphics processing units considering the sizes of the images as well as the amount data being carried. D. Petcu et al.[8] used satellite imagery in their case to study and illustrates how to migrate the traditional image processing applications to Grid infrastructures for different roles of image processing. A distributed infrastructure is Grid infrastructures where computing resources are not administered centrally, open standards are used, and non-trivial quality of service is achieved. They provided powerful tools for remote sensing data sharing and processing. M. Kol´ınov´et al. [9] gave an overview of satellite data issues, their usage in environmental data processing and then discussed satellite image analysis as applied to air pollution caused by the concentration of dust particles. F.A. Farrag et al. [10] used temporal multispectral satellite image to locate the horizontal dispersion of air pollution caused by a cement factory. Their study used software to show that multispectral images could be used as global tools for locating and monitoring industrial air pollution.

3. Implementation

The diagram of the proposed detection and extraction procedure is illustrated conceptually in Figure 2. The methodology was designed placing great emphasis on computer vision and digital image processing algorithms for processing satellite images. The whole process is divided in to four parts. Firstly, rectification of imagery, then edge detection using Canny method. Morphological closing operations followed on the canny edged operated imagery. Next follows the use of Hough Transform for boundary lines delineation. Initially, the image was rectified to the local coordinate system using a second order polynomial transformation. Measurements of the ground coordinates of the control points were carried out in the field by applying Global Positioning System (GPS). The residual Root Mean Square (RMS) error was 0.6152 meter, for X is 0.4119 meter and for Y is 0.4570 meter. The imagery was geometrically corrected using 17 sets of control points spread around the local area of interest. The resampling process was carried out using nearest neighbor method in order to avoid any smoothing to the original image data. More detailed explanation on this process could be obtained from [11]. Now the imagery is ready for any morphometric assessment as its errors planimetrically have been corrected.

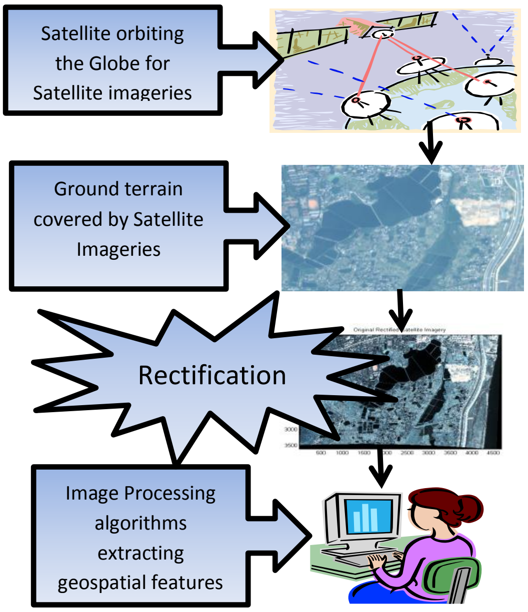

Fig.2 Our Computer Vision concepts of digital cadastre

3.1 Satellite Imagery dataset

In this study we use 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 Satellite Imagery Edge Detection

Edges are significant local changes of intensity in an image. Edges typically occur on the boundary between two different regions in an image. The main goal is to produce a line drawing of a scene from an image of that scene as such important features can be extracted from the edges of an image e.g., corners, lines, and curves. These features are then used by higher-level computer vision algorithms for recognition purposes. There are many methods of edge detection with Canny and sobel being the most popular ones. So we applied both Canny and Sobel edge detection methods to the rectified grayscale imagery to identify all the edges on the images as shown in Fig 5 and Fig 6.

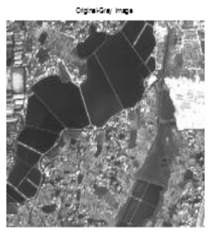

Fig.3 Originalsatellite imagery

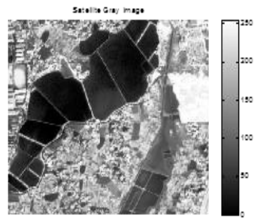

Fig.4 Gray satellite imagery

The Canny edge detection operation produced images that we followed with morphological operations. The sobel edge operated imagery contains 'edge breaks' as such is not suitable for our imagery, refer to Fig 5.

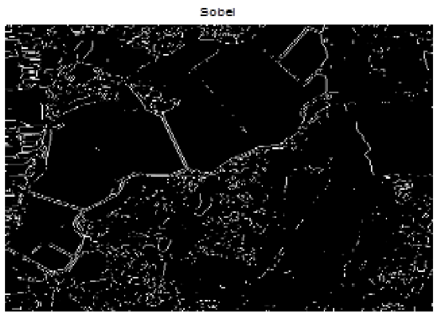

Fig 5 Sobel edge detection method

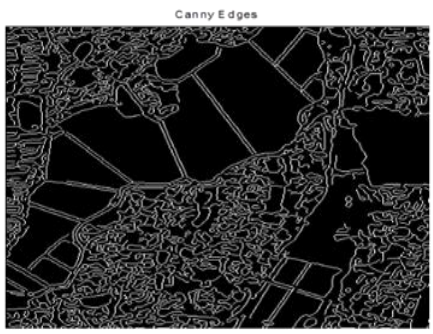

Fig. 6 Canny edge detection method

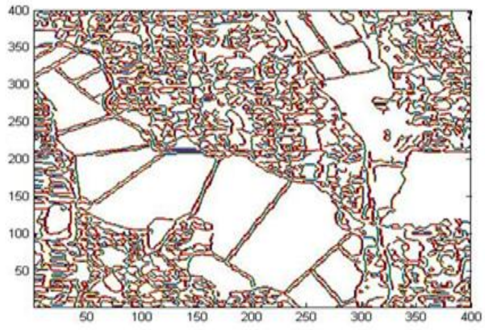

Fig. 7 Contoured image of canny edged detected imagery

3.3 Satellite imagery Morphological Operations

Morphology method could be divided to binary and gray. Its basic thought is to measure and detect corresponding shapes in an image in order to achieve the goal of analyzing and recognizing image by using structure elements with some given forms. The foundation of mathematical morphology is binary morphology, and its fundamental transforms include dilation, erosion, open, and close. Morphological operations are excellent tools for image filtering. Dilation is a kind of vector addition while erosion is a kind of vector subtraction [12]. 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 [13].

We used the dilation and erosion operations on the gray imagery with a 5x5 structural element which gives the following results: Fig 8 and Fig 9. Despite the gray image is the same for the two morphological operations, the dilated image appears thicker in boundary and having better contrast, vis-à-vis the eroded image that has relatively thinner boundary and less contrast, so much darker. This shows that dilation adds pixels to boundaries making them thicker whereas erosion removes pixel from boundaries, making them thinner. This kind of operation is 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 10. 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. So we then repeat the process using a larger 4x4 structural elements and Fig12 is as a result of using 5x5 structural elements. Based on our subjective assessments, we opted for Fig.11. This resulted in a cleaner image showing all the field boundaries as black objects against white background, Fig 11. We successfully applied the morphological closing operations on the gray image to extract the farmland features. Eureka!.

Here morphological closing operations are applied to the imagery using varying sizes of structural elements. Since image processing is an experimental science, we got a satisfying result with the size being 4, Fig 11. At first we applied structural element of size 2 as in Fig 10. In Fig 11 and Fig 12, we have separated the farmlands from the entire imagery using 4x4 and 5x5 structural elements.

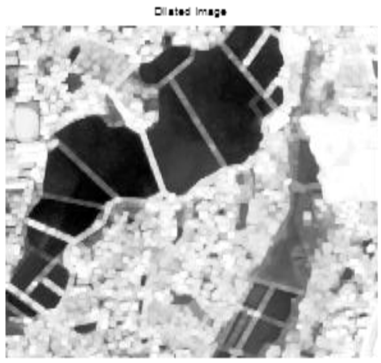

Fig.8 Dilated Image using 5x5 Structural elements

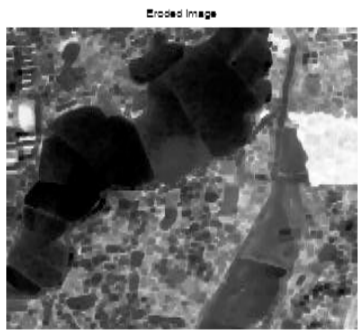

Fig. 9 Eroded image using 5x5 structural elements

Fig. 10 Dilation followed by erosion using 2x2 structural elements

Fig.11 Dilation followed by erosion using 4x4 structural elements

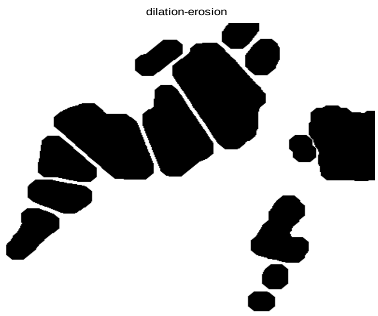

Fig.12 Dilation followed by erosion using 5x5 structural elements

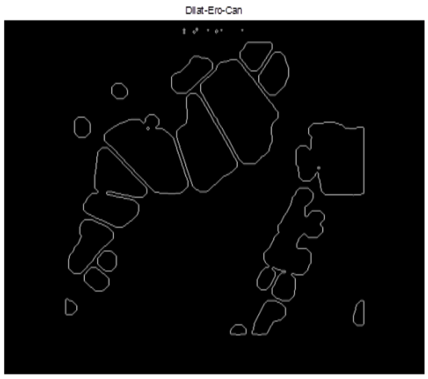

Fig. 13 Segmented image delineating the farmland fields

3.4 Satellite Imagery with Hough Transform HT

In Hough transform, a point (x_i, y_i) and all the lines that pass from it are considered. Infinitely many lines pass through (x_i, y_i), all of which satisfy the slope-intercept equation

$$y_i = ax_i + b \qquad \text{(eq. 1)}$$

where, a is the slope of the line and b is the y intercept. For all lines that pass through a point (x_i, y_i), there is a unique value of b for a.

$$b = -x_i a + y_i \qquad \text{(eq. 2)}$$

The difficulty in slope-intercept approach is that the slope of the line moves towards to infinity when the line is about vertical and the slope is 0 when the line is horizontal. To handle this problem, in the Hough transform normal representation of a line can be used as follows.

$$r = x \cos\theta + y \sin\theta \qquad \text{(eq. 3)}$$

where, r represents the length and θ is an angle from the origin of a normal to the line.

The computational attractiveness of the Hough transform arises from sub-dividing the rθ parameter space into so-called accumulator cells [14]. The transform is implemented by quantizing the Hough parameter space into accumulator cells. In the beginning, the accumulator cells are set to zero. As the algorithm runs, each (x_i, y_i) is transformed into a discretized (r, θ) curve and the accumulator cells that lie along this curve are incremented. Resulting peaks in the accumulator array represent strong evidence that a corresponding straight line exists in the image.

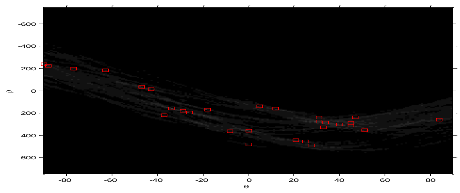

Fig 14 Hough Transform peaks

Fig. 15 Final extracted farmland boundaries from the satellite imagery in colors

4. Results and Discussion

The developed algorithm for farmlands detection, extraction and delineation performed well with the given samples of satellite imagery. This could be ascertained by examining the figures all through. Our features of interest, farmlands are neatly and accurately segmented and delineated with even their thin boundaries as well extracted for further surveying analysis.

Based on the visual assessment of our results vis-à-vis the farmlands' boundaries we can successfully state that the farmlands were detected, extracted and delineated, though there were some omission in the delineation as the HT could not get them. In the study area there are roughly a total of 30 farmland boundaries. Of these boundaries, 22 were successfully delineated with the accuracy rate of 73.33% as shown in Table 1.

Table 1. Error matrix of the delineated farmland boundaries

	Count	Percentage %
Delineated Boundaries/Ref. Boundaries	22/30	73.33

5. Conclusions

Popular edge detection based method, with morphological closing operations, was combined with Hough transform to detect and extract the features of interest, farmlands. According to our satellite imagery, a 4x4 structural element was suitable for the task. This shows that computer vision algorithms could suitably be used as a novel option to delineate farmlands and other geospatial features for the purpose of rendering statutory surveying tasks.

5.1 Further Works

- With further improvements, the spatial features extracted may be used for urban planning, ecological planning, disaster estimation, mapping and a host of other environmental tasks.
- We intend to see to the development of a comprehensive system for the management of geospatial features. That is building intelligent system that automatically learns meaningful feature representations from a massive amount of satellite image data.
- We are also in the near future looking at the possibility of using more robust classifiers to classify the imagery for more effective morphometric results.

Acknowledgement

This research work was fully supported by the National Research Foundation for the Doctoral Program of Higher Education of China and the Kano University of Science and Technology, KUST, Wudil, Nigeria, through the Educational Trust Fund, ETF, Nigeria. Mr. Xu Bing is also acknowledged for providing the only available satellite imagery for the research.

References

[1] A. S. Mohammed, S. Rusthum, Object-oriented image processing of an high resolution Satellite imagery with perspectives for Urban growth, planning and development, International Journal of Image Processing, Vol. 2 Issue 3, 2008

[2] Lecture Note, GS/CE400.01 Introduction to Surveying; The Flat Earth Society Strikes Again, Geodetic and Geo-information Science Section, Department of Civil and Environmental Engineering and Geodetic Science, Germany, 2001. http://www.vermessungsseiten.de/englisch/vermtech/index.htm.

[3] A. M. Montufo, The Use of Satellite Imagery and Digital Image Processing in Landscape Archaeology. A Case Study from the Island of Mallorca, Spain, Geoarchaeology, An International Journal, Vol. 12, No. 1, 71–85,1997.

[4] Z.S. Chen, J. Fan, A Grid Environment Based Satellite Images Processing, The First International Conference on Information Science and Engineering, ICISE, 2009.

[5] IDRISI: Introduction to Remote Sensing and Image Processing, Chapter 3 Introduction to Remote Sensing and Image Processing, IDRISI Guide to GIS and Image Processing Volume 1, 2006.

[6] S.A. Hsu, Using Infrared Satellite Image Processing to Rapidly Estimate Coastal Flooding Induced by Tropical Cyclones, Congress on Image and Signal Processing, 2008.

[7] M. Rumanek, T. Danek, A. Lesniak, High Performance Image Processing of Satellite images using Graphics processing units, IEEE International Geoscience and Remote Sensing Symposium, IGARSS, 2011.

[8] D. Petcu, S. Panica, A. Eckstein, Satellite Image Processing on Computational Grids Proceedings of the 9th WSEAS International Conference on Automatic Control, Modeling & Simulation, Istanbul, Turkey, 200.7

[9] M.Kol´ınov´a, A. Proch´azka, M. Slav´ık, Satellite images in environmental data Processing, Institute of Chemical Technology, Prague.
[10] F. A. Farrag, The Role of SPOT Satellite Images in Mapping Air Pollution Caused by Cement Factories, International Archives of Photogrammetry and Remote Sensing. Vol. xxxiii, Part B7. 2000.
[11] U. Babawuro, Z. Beiji, Multi-resolution Satellite Imagery Rectification using Bi-linear Interpolation Method for Quantitative Analysis, International Journal of Digital Content Technology and its Applications, JDCTA, Volume6, No.2, 2012 doi:10.4156/jdcta.vol6.issue2.13.
[12] U. Babawuro, Z. Beiji, Satellite Imagery Cadastral Features Extractions using Image Processing Algorithms: A Viable Option for Cadastral Science, International Journal of Computer Science Issues IJCSI, Vol. 9, Issue 4, No 2, July 2012 ISSN (Online): 1694-0814, www.IJCSI.org.
[13] R.C Gonzalez, R.E. Woods, S.L Eddins, Digital Image Processing using Matlab, Pearson Education Inc, Prince Hall, 2009.
[14] R.C. Gonzalez, R.E. Woods Digital Image Processing, Third Edition, Pearson Education Inc, Prince Hall, 2010.

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. He has authored several papers in international journals and conferences. He is a professional member of Nigerian Computer Society, NCS, and Computer Registration Council of Nigeria, CPN. His research interest includes image and video processing, pattern recognition, feature extraction and machine learning.

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 as a Visiting Scholar.