Building Area Detection of Urban region based on GIS

Khaing Cho Moe, MyintMyintSein
University of Computer Studies, Yangon, Myanmar
khaingchomoe.ucsy@gmail.com, myintucsy@gmail.com

Abstract

Rapid urbanization and urban growth is continuing to be one of the crucial issues of global change affecting physical dimensions of cities. In this study, building growth change detection is investigated as buildings are one of the most dynamic structures in urban areas. The modified MBI is applied to extract building features to know how much area has changed.In this system, height information is not considered for building extraction because of without using multispectral band images and Depth.To accurate the position of building extraction index in change detection process, image registration is used that seeks to remove the two-date images geometric inconsistent object using SURF and RANSAC. It is significantly reduce error rates and improve overall accuracy of change detection process.The experiments show that the proposed change detection algorithms can achieves satisfactory correctness rates with a low level of error rate, and give better result than SIFT feature extraction method in image registration.

Keyword:*urban growth, modified MBI, SURF, SIFT, change rule.*

1. Introduction

Urban growth detection is very important in urban monitoring such as the detection of new buildings or the discovery of modifications in the existing ones with the use of GIS and Remote Sensing (RS). RS technology provides data from which updated land cover information can be extracted efficiently and cheaply that is presented in [1]. Land use change detection has become a major application of remote sensing data.

Traditional satellite or airborne image-based automatic building change detection methods are mainly based on radiometric information analysis.The images acquired at two dates are compared pixel by pixel based on the original spectral information. In particular, if particular objects are of interest, as in our case buildings, it is very difficult to extract those without height information. Many irrelevant changes will be mixed with building changes, when the data are acquired from different sensors or acquired under different imaging geometrics.

Moreover, building may be surrounded by dense vegetation; they may have the same color as tree or grass. Awrangjeb*et al*. [2] proposed NDVI only and therefore can't distinguish between a green building and a green tree. Jin and Davis [3] presented an automated building extraction strategy that simultaneously exploited structural, contextual and spectral information.They applied morphological profiles to extract structural information, reliable contextual information and bright buildings. The final result was obtained by integrating the results of the three different information sources.The problem of this morphological profile causes to commission and omission error. So, X. Hang and L. Zhang [4] and [5] exploited a new method Morphological Building Index (MBI) to extract building area without commission and omission error. The proposed framework was validated on an Ikonos image and World View-2 images that is implemented in an object-based environment, where a geometrical index and a vegetation index are then used to remove noise from narrow roads and bright vegetation. But this method is applied only on multispectral bands of high resolution satellite images and can't detect low resolution images such as Google Earth image.

Then, image registration is a fundamental task in change detection process used to rectify two images which are taken at different time, from different sensors or different viewpoints in [6].Automatic registration of remote sensing images is a difficult task because it must deal with the intensity changes and variation of scale, rotation and illumination. To perform image registration, it is required three steps: feature detection (SURF method), inliers feature matching (RANSAC) and derivation of transformation function (Affine Transform).

In this system, we proposed urban growth detection system with three parts: image registration, building feature extraction and change rule. Image registration is carried out by combining of SURF (Speed-Up Robust Feature) and RANSAC for the same scene with different angles of yearly images. And then resulted registered image is used to extract building area with modified MBI and finally changed areas are detected by applying change rule. The rest of the paper is organized as follow. Section 2 describes the system overview and section 3 discusses methodology of our proposed system containing image registration, modified MBI and change rule. Section 4 illustrates the experimental results and section 5 concludes the paper.

2. System Overview

The system is divided into three parts. Firstly two input images are rectified by using SURF registration methodto get registered images.Itcan accurate certain position of two images in change detection process as various viewpoints with different sensors. Then, the system is carried on building feature extraction process by modified MBI method [7] that have human intervention is not required and it is solely unsupervised process.This modified method is effective for building only extraction and convenient in even low resolution satellite imagery such as Google Earth. The challenge of original MBI is that multispectral band of high resolution satellite image can only be applied and haven't considered registration method for better accuracy.Our system can do both high and low resolution satellite image with rectified images. Then resulting building area image is processed by change rule and the final increase buildingsare displayed.

3. System Methodology

It contains three parts: Image Registration modified Morphological Building Index and Change Rule.

3.1. Image Registration

Image registration is a crucial step in most image processing tasks for which the final result is achieved from the combination of various resources. It presents a way to extract distinctive invariant features from images that can be used to perform reliable matching between different views of an object/scene. It has three parts: feature extraction, outlier rejection and reconstruction.

3.1.1. SURF Feature Point Extraction method

The Speed-Up Robust Feature (SURF) method is quickly searching for matching points. It is robust image detector and descriptor so it reduces the computation time and causes low dimensionality so that SURF is better than other method with respect to repeatability, distinctiveness, robustness and speed.SURF detector is mainly based on the approximated Hessian Matrix [8] which causes good performance and good accuracy. Suppose in the image I, X=(x,y) is the given point, then the Hessian metrics H(x , σ) for the X having the Scale σ, is defined in eq(1):

$$H(X,\sigma)=\begin{bmatrix} L_{xx}(X,\sigma) & L_{xy}(X,\sigma) \\ L_{xy}(X,\sigma) & L_{yy}(X,\sigma) \end{bmatrix} \quad (1)$$

whereL_{xx}(X , σ) is the convolution of the Gaussian second order derivative with the image at point*X*, and similarly forL_{xy}(X , σ) and L_{yx}(X , σ).

3.1.2. Random Sample Consensus (RANSAC) algorithm

After matching control point pairs have been identified, RANSAC algorithm is used to eliminate the outlier control point pairs of obtained a set of observed data.It can cope a large proportion of outliers in the input data that is proposed in[9].

Algorithm:

1. Select random sample of minimum required size to fit model
2. Compute a putative model from sample set
3. Compute the set of inliers to this model from whole data set

Repeat 1-3 until model with the most inliers over all samples is found.

The advantages of using RANSAC outlier rejection method are it can robust to outliers and computational time grows quickly. And the number of hypothesis is sufficiently large that RANSAC gives very similar results.

3.1.3. Affine Transformation

The most commonly used registration transformation is the affine transformation which is sufficient to match two images of a scene taken from the same viewing angle but from differentposition.

Given the refined matching point pairs, building the mapping function and get the affine transformation parameters to resample the sensed image and perform image registration. After affine transform is applied in the resulting of RANSAC method, the output of the registered image is obtained.

3.2. Modified Morphological Building Index

The basic idea of MBI is to build the relationship between the spectral-structural characteristics of buildings and the morphological operator, whichare summarized as follows.

- Brightness
- Local contrast
- Size and Directionality
- Shape

This method uses multispectral bands for high resolution images. Now we use low resolution image of three band color. The modified MBI is defined by describing the characteristic of building feature especially color of building roof and image intensity value.The system runs on low resolution satellite images so their resolution and brightness of intensity values are very low. In order to achieve this problem, modified MBI is proposed as the following steps:

Step 1: Enhancement of Image

The input low resolution registered image is transformed to high contrast image by applying with only red intensity value and stored as the brightness valuewhich is computed by Eq. 2.

$$g = T(f_R(x,y)) \quad (2)$$

where $f_R(x,y)$ is the intensity transformation of red color-space image, g is the result of enhanced red band image using histogram adjust In [10], Original MBI is applied in multispectral band images of high resolution satellite images. They used enhancement process by using brightness value from this multispectral band..Now our method gives for both high and low resolution of various satellite images with the use of only red color enhancement.

Step 2: Construction of MBI

The spectral-structural characteristics of buildings (e.g., contrast, size and directionality) are represented using the Differential Morphological Profile (DMP).The construction of MBI contains three steps.

*(i) White top-hat by Reconstruction*can be computed by Eq. 3.

$$W\_TH(d,s) = g - \gamma_b^{re}(d,s) \quad (3)$$

where γ_b^{re} represents the opening-by-reconstruction of the brightness image, and sindicates a flat and disk-shaped linear structuring element (SE), respectively.

*(ii) Morphological Profiles (MP)*of the white top-hat is defined as Eq. 4 and 5.

$$MP_{W\_TH}(s) = W\_TH(s) \quad (4)$$

$$MP_{W\_TH}(s) = 0 \quad (5)$$

(iii) Differential Morphological Profiles (DMP) of the white top-hat is calculated as Eq. 6.

$$DMP_{W\_TH}(s) = |MP_{W\_TH}(s+\Delta s) - MP_{W\_TH}(s)| \quad (6)$$

where Δs is the interval of the profiles and $s_{min} \leq s \leq s_{max}$.

MBI is defined as the average of the DMPs of the white top-hat profiles defined in eq. 7 and 8since buildings have large local contrast within the range of the chosen scales. Thus

$$MBI = \frac{\sum_s DMP_{W\_TH}(s)}{D \times S} \quad (7)$$

$$S = \left(\frac{s_{max} - s_{min}}{\Delta s}\right) + 1 \quad (8)$$

where*D* and *S* denote the numbers of disk and scale of the profiles, respectively.

Step:3 Building extraction

The final building extraction step is decided by using predefined threshold value in order to classify these *MBI (x)* pixelsbecause of different resolutions and image capturing time.

IF $MBI(x) \geq t_1$,
THEN $map_1(x) = 1$
ELSE $map_1(x) = 0$

where MBI*(x)* and $map_1(x)$ indicate the value of *MBI* and the initial label for pixel *x*. t_1 is threshold value and set t_1=5 for the best result for the system.

3.3. Change rule

After building only areas are extracted by modified MBI in two images, matched-based change rule is applied to get final change/increase building areas.

$$
\begin{aligned}
&\textit{If} \quad \overline{map}_1(i) \cap \overline{map}_2(i) \\
&\quad \textit{then} \quad C(i) = 0. \\
&\textit{elseif} \quad \overline{map}_1(i) \cap map_2(i) \\
&\quad \textit{then} \quad C(i) = 1. \\
&\textit{elseif} \quad map_1(i) \cap \overline{map}_2(i) \\
&\quad \textit{then} \quad C(i) = 0. \\
&\textit{else} \quad map_1(i) \cap map_2(i) \\
&\quad \textit{then} \quad C(i) = 0. \\
&\textit{end} \qquad i \in 1,2,3,\ldots,N
\end{aligned}
$$

where $map_1(i)$ and $map_2(i)$ are the output value(0 and 1) of modified MBI method. '0' means no building and '1' means building. The *i* is the same pixel of first and second images and N is the number of pairs of the corresponding building objects where *C(i)* represents whether the object *i* is changed, with 0 and 1 for non-change and change, respectively.

4. Datasets

The analysis of the building change detection is carried out based on ten year satellite images from Google Earth acquired between 2004 and 2014. The first five years and second five years images are divided and which portion is more or less developed. Those all images include three visible bands such as red, green and blue. The study area lies in the downtown area of Yangon city and covers approximately ten seconds coordinates (96056.60 square meters) for one image.It is a typical urban landscape of Myanmar where dense residential and commercial areas are mixed together.Due to the rapid infrastructure construction and updated developing country, the study area shows complicated land-cover change.

In order to effectively evaluate building change detection algorithms, we use manually delineated ground truth maps of buildings change. Newly and rebuild building area define changed building ones in our system.

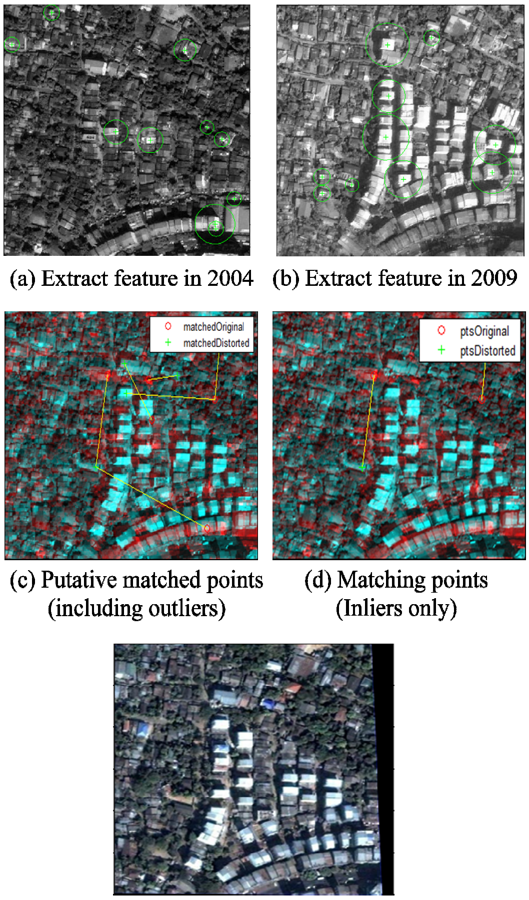
5. Experimental Results

The experiment of the system is testedin Sanchaung townships, Yangon.The following figure 2 shows an example of ten year successive images from 2004 to 2013.

(a) 2003 image (b) 2009 image (c) 2014 image

Figure2.An example of imageslocated inSanchaungtownships, Yangon.

Then, these ten year images are divided into two parts the first five years and second five years in order to know what year section is more or less developed. Then registration process is carried out to rectify various anglesposition of satellite images usingSURF feature extraction method and RANSAC.Figure 3(a) and 3(b)shows features extraction result of SURF method on two images and 3(c) illustrates matching point pairs of two images that include both corresponding point pairs and outliers but RANSAC algorithm is applied in this step so miss-matched points or outlier points is removed in figure 3(d). After removing outliers, affine transformation is utilized to resample the sensed images in figure 3(e).



(a) Extract feature in 2004 (b) Extract feature in 2009

(c) Putative matched points (including outliers) (d) Matching points (Inliers only)

(e) Registered Image

Figure 4.Image registration process using SURF

The building extraction process is carried out using modified MBI as shown in figure 4.In these figures, white area means building areas and black area indicates open space areas that have no buildings and can build anymore. The final output is shown in figure 5 in which increased/change building area is detected.

(a) 2004 image (a) 2009 image

Figure 4.Building extraction result usingmodifiedMBI.

Figure 5. Output of proposed change detection result using change rule

The following table is the processing of SURF feature method and RANSAC algorithm to obtain matching points pairs that is tested in ten years images of Sanchaung Townships, Yangon.

In experiment, errors may occur when many crowded cars on the road lead to miss building extraction because of urban downtown area is our research target. Few building area can't detect in this testing when resolution and contrast is low from Google Earth. The system can detect high resolution commercial satellite images such as Ikonos and can also detect arial images acquired by airplane and high quality camera is used to capture to grab multispectral band image in March, 2014.

Table 1: Feature Points Information using SURF

No.	Year	SURFPoints		Match points	
		Sensed Image	Reference Image	SURF	SIFT
1	2004				
2	2005	393×1	471×1	20	3
3	2006	471×1	502×1	29	5
4	2007	502×1	556×1	67	6
5	2008	556×1	612×1	152	12
6	2009	612×1	570×1	31	4
7	2010	570×1	612×1	31	4
8	2011	612×1	638×1	30	3
9	2012	638×1	477×1	47	5
10	2013	477×1	566×1	26	4

The Panchromatic image can also be used to apply our method that can give greater accureacy and correctness that is from Ikonos satellite images. This is shwon in figure 6.

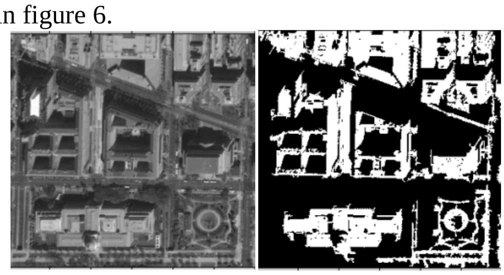


Figure6.portion of a 1-meter resolution panchromatic image produced by Ikonos sensor.

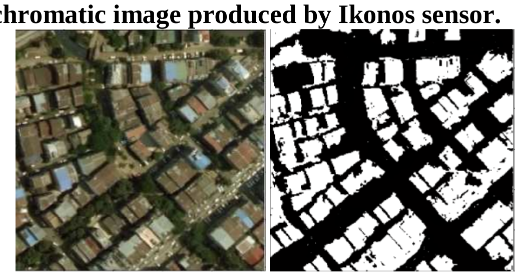


Figure 7: Arial image of Yangon downtown region.

In figure 7, arial high resolution satellite image is tested in improved morphology method. The Table 1 describes comparison between SURF and SIFT of feature points detection and final matched point pairs of SURF feature are significantly more than SIFT ones. The performance of the proposed modified MBI and change rule is compared with change detection approach of MBI-based CVA in [10]. MBI-based CVA focus on building change detection. The spectral bands are replaced by the multi-temporal MBI feature images for CVA. It contains the salt-and-pepper effects of pixel-based change detection approaches.

The evaluation performance is calculated by the following equation. To test the performance of the proposed system, we use these evaluation measures (completeness, correctness, quality) in Table 2.

$$Correctness = \frac{DB}{RB}$$

$$Completeness = \frac{RF}{DB}$$

$$Quality = 100 * \frac{TP}{TP + FN + FP}$$

- TP(True Positive): number of buildings detected both manually and with the automatic approach.
- FP (False Positive): number of buildings detected by the automatic approach but not manually.
- TN (True Negative): number of buildings detected manually but not by the automatic approach.
- FN (False Negative): number of undetected buildings.
- DB: detected buildings at least partially overlapped with the reference buildings.
- RF: reference buildings overlapping the detected buildings.
- The correctness value indicates the percentage of the detected building objects that are at least partially overlapped with the reference buildings.
- The completeness value refers to the percentage of reference buildings overlapped the detected buildings.
- The quality measures the absolute quality of the detection model.

Table 2 .Accuracy assessment of the proposed method

Quantitative measures	MBI-based CVA	Proposed Method
Correctness	81.75%	97.87%
Completeness	74.79%	92.45%
Quality	64.09%	89.07%

6. Conclusion

The contribution of this paper is to propose the building growth detection using modified MBI for satellite images which is able to solve various satellite images only with three spectral colors without using multispectral band images because the original MBI is only for multitemporal high-resolution imagery. The characteristic of the proposed method is unsupervised and it is implemented without any training samples so it is able to achieve higher correctness rates and lower average errors than other supervised algorithm. The effectiveness of the proposed method has been validated on Google Earth image of Yangon downtown region in Myanmar with different kinds of building growth including construction, updating and rebuild. The challenge of the proposed system is that user doesn't know detail position (latitude and longitude) of change area and very low quality satellite image is weak to perform using modified MBI method.

References

[1] C. TARHAN, "Detection of environmental and urban change using remote sensing and GIS", thesis book, October. 2007.

[2] Awrangjeb, M. Ravanbakhsh, and C.S. Fraser, "Automatic building detection using Lidar data multispectral imagery", Proceedings of the Digital Image Computing: Techniques and Applications, Sydney, Australia, pp. 45-5, 2010.

[3] X. Jin and C.H. Davis, "Automated building extraction from high resolution satellite imagery in urban areas using structural, contextual, and spectral information", *EURASIP J. Appl. Signal Process.,* vol. 14, pp. 2196-2206, Jan. 2005.

[4] X. Hung and L. Zhang, "Morphological building/ shadow index for building extraction from high resolution imagery over urban areas", IEEE J. Set. Topic Appl. Earth Obs. Remote *Sens.*, vol. 1,pp. 161-172, Feb. 2012.

[5] X. Hung and L. Zhang, "A multidirectional and multiscale morphological index for automatic building extraction from multispectral GeoEye-1 imagery", *Photogramm. Eng. Remote Sens*., vol. 77, no. 7, pp. 721-732, Jul. 2011.

[6] D. Suma, S. Vikas, and Sh. Bhudev, "Remote sensing image registration techniques: a survey",In: Proc ISISP, vol. 6134, pp. 103-12, 2010.

[7] K. C. Moe and M. M. Sein, "An unsupervised technique for building change detection in urban area", *Int. J. Computer Application,* vol. 106, no. 18, pp. 31-35, New York, November Edition, 2014.

[8] P. M. Panchal, S.R. Panchal and S.K. Shah, "A comparison of SIFT and SURF", *Int. J. Innovative Research in Computer and Communication Eng,* vol. 1, no. 2, April, 2013.

[9] M. A. Fischler and R.C. Bolles, "Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography", *Communications of the ACM*, 24(6): 381-395, 1981.

[10] Y. Tang, X. Huang and L. Zhang, "Fault-Tolerant building change detection from urban high-resolution remote rensingimagery ", IEEE Geosci. Remote Sens.Lett, vol.10, No.5, Sept 2013.