A COMPARITIVE STUDY OF BUILDING EXTRACTION METHODS FROM VHR SATELLITE IMAGES

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ABSTRACT:

Extraction of buildings from very high resolution (VHR) satellite images is a recent research trend in remote sensing and computer vision. The principal approach employed so far are based on classification, segmentation and edge detection of buildings from satellite images. In this paper, we compare three existing methods for the extraction of buildings from satellite images. The experimental satellite images to extract buildings with different shapes, sizes, colors and patterns are taken from Massachusetts Buildings Dataset having spatial resolution of 1 meter. In the first method, k-means clustering algorithm is applied to classify the pixels into a number of classes which then is followed by morphological operations to extract the buildings. The second method employs Fuzzy C means clustering instead of K means clustering to extract buildings. Thirdly, a method that measures the geometric saliency of buildings by leveraging the meaningful geometric features specialized for describing buildings is implemented. The third method is totally unsupervised and free of any training strategies. The performances of the three methods for the extraction of buildings are evaluated using qualitative and metric analyses. The experimental results obtained are discussed in the paper.

I INTRODUCTION

Remote sensing is the acquisition of information about an object or phenomenon without coming into physical contact. This enables us to obtain the information about the land, sea and atmosphere by the special cameras mounted on satellites to capture remotely sensed images, which help the researchers to "sense" things about the Earth. Remote sensing applications primarily involve interpretation and analysis of electromagnetic radiations interacting with earth and its atmosphere utilizing data collected by earth observation (EO) sensors on-board aerial or satellite platforms. The EO system with its ability for a synoptic view, repetitive observations at different spatial, spectral and radiometric resolutions has been widely accepted as an indispensable tool for natural resources inventory, monitoring, generating data for resource management planning, weather forecast, disaster damage assessment and climate change studies. The improvements in observation capabilities are not only in spatial, spectral, temporal and radiometric resolutions, but also in their global coverage as well as value-added products. The application of remote sensing is numerous and in this paper we have taken very high resolution satellite images to extract buildings from their surroundings.The rapid growth of sensor technologies, such as airborne and terrestrial laser scanning, and satellite and aerial imaging systems, poses unique challenges in the detection, extraction and modelling of buildings from remote sensing data. In fact, building detection, boundary extraction, and rooftop modelling from remotely-sensed data are important to various applications, such as the real estate industry, city planning, homeland security, automatic solar potential estimation, and disaster (flood or bushfire) management. The automated extraction of building boundaries is a crucial step towards generating city models. In addition, automatic building change detection is vital for monitoring urban growth and locating illegal building extensions.

Therefore, intelligent and innovative algorithms are the need of the hour. This paper focuses on the study of existing methods for the extraction of buildings from remotely sensed data.

II LITERATURE SURVEY

There were many studies for more than two decades that were focusing on extraction of buildings from other land cover classes, the success of automatic building extraction and modeling is still largely impeded by scene complexity, incomplete cue extraction, sensor dependency of data and so on. In a paper [8], automatic building extraction was performed using multiresolution segmentation where for classification they employed object- oriented fuzzy classification. It is reported that the clear edges of buildings were not extracted but coincided with the original image of urban buildings. Two simplified versions of the object counting algorithm have been developed by Christophe and Inglada [1]. These versions aimed at providing a likelihood map of the regions containing objects of interest where they followed the same steps than in the original algorithm, i.e., segmentation, vectorization algorithms. In another paper [6], fuzzy landscape was used in which foreground and background pixels were automatically determined and a bi-partitioning was obtained using a graph based algorithm called Grab cut but shadow detection. Split and merge segmentation and clean-up methods were used [3] in which texture based extraction was proposed and to increase the extraction rate, some more parameters like shape, shadow were considered. The spectral characteristics of the high resolution satellite images were considered which in turn produced building regions whose shapes were appropriate to rectangles [7]. In the paper [5], buildings characteristics were taken into consideration from the spectral, geometrical, and contextual information of high–spatial-resolution images in order to achieve better extraction. For automatic building extraction from aerial and satellite imagery, a convolutional network was designed and it was reported that attaining a universal building extractor addressing various issues was a challenge [11]. Segment detection for rapid automatic building extraction from very high resolution (VHR)was proposed[10] but still more accurate extraction of arbitrarily shaped buildings on larger data sets was reported as a challenge. Motivated by the above study, it is planned to perform a comparative study of three building extraction algorithms. Section-III of this paper describes in detail the existing building extraction algorithms while Section-IV lists the experiments conducted along with the results and Section-V reports performance evaluation. Section-VI presents discussion of experimental results. The last section draws the conclusion.

III BUILDING EXTRACTION ALGORITHM

A.Mathematical Morphology based Kmeans Building Extraction Algorithm

In this work, an approach that automatically extracted buildings from very high resolution satellite images based on mathematical morphology [2] was proposed. The method integrates morphological top hat filters and K means clustering algorithm to extract buildings. In the original RGB image, Top Hat Filter has been applied. It computes the morphological opening of the image and then subtracts the result from the original image. Using this approach, the pixel values are classified as white and black pixel by subtracting the original image with Top hat filtered output image and white pixels in the image are obtained by subtracting Top hat filter from the original image, giving the black pixel portion in the image.

White Top-hat transformation

$$(I_{WTH}) = I - I \circ S \quad \text{----(1.1)}$$

Black Top-hat transformation

$$(I_{BTH}) = I \bullet S - I \quad \text{----(1.2)}$$

$$I_{En} = I + I_{WTH} - I_{BTH} \quad \text{----(1.3)}$$

Where $_{WTH}$ White Top Hat transformation,I denotes the input image ,IoS & $I \bullet S$ represents morphological opening and closing operations respectively.This enhanced image I_{En} is given as an input for K-means clustering algorithm and the centroid value is fixed. If the obtained value is less than the centroid value means, it is shaded as black else it is shaded as white. For both the black and white portions of the image, median filter is applied to remove noise and also to improve the result of later processing. After performing the above mentioned process a clear edge is obtained, Further this undergoes connected component labelling by determining major and minor axis. The factors such as area, eccentricity ratio are determined for both black and white portions of the images. The resultant images are merged together for better clustering results.

B. Fuzzy C means Clustering Algorithm for Building Extraction

The fuzzy *c*-means algorithm is very similar to the *k*-means algorithm:

Fuzzy C- means technique is one of the unsupervised clustering techniques used in image segmentation [9]. Its idea depends on clustering data into two or more classes only by known number of classes that image will cluster to it. Initially, the number of clusters is fixed as 4 . The coefficients are randomly assigned to each data point for being in the clusters. The algorithm is repeated until convergence (that is, the coefficients' change between two iterations is no more than Ɛ The given sensitivity threshold) is achieved. The value of Ɛ is fixed as 140 and above for better segmentation result.

Any data point *x* has a set of coefficients giving the degree of being in the *k*th cluster $w_k(x)$. With fuzzy *c*-means, the centroid of a cluster is the mean of all data points, weighted by their degree of belonging to the cluster,

$$\mu_{ij} = 1 / \sum_{k=1}^{c} (d_{ij} / d_{ik})^{(2/m-1)} \qquad \text{---- (1.4)}$$

$$v_j = \left(\sum_{i=1}^{n} (\mu_{ij})^m x_i\right) / \left(\sum_{i=1}^{n} (\mu_{ij})^m\right), \forall j = 1, 2, \ldots c \qquad \text{----(1.5)}$$

where,

'n' is the number of data points. 'vj' represents the j^{th} cluster center. 'm' is the fuzziness index m € [1, ∞]. 'c' represents the number of cluster center. 'µij' represents the membership of i^{th} data to j^{th} cluster center. 'dij' represents the Euclidean distance between i^{th} data and j^{th} cluster center.

C.Geometric Saliency based Building Extraction Algorithm

In this method, the geometric saliency of the buildings [4] was used for building extraction. The very high resolution satellite image of buildings was taken and the junctions were extracted from the buildings. This method preserves the geometric of buildings without any deviation. As well as the buildings detected in this method have a clearer boundary and less redundant cluttered areas. The geometric building index (GBI) associates each pixel p with a saliency measuring the possibility of the pixel belonging to buildings, which is the summation of saliency inside parallelogram of all junctions. Thus, for a pixel p 2 in U, its corresponding GBI is calculated by:

$$\mathrm{GBI(p)} = \sum_{\jmath \in \mathcal{J}} \left(\omega_\jmath^{(1)} + \omega_\jmath^{(2)}\right) \cdot \mathbb{1}_{\mathbf{p} \in R_\jmath}, \qquad \text{----(1.6)}$$

where J is the list of junctions detected in image U, and $\mathbb{1}_{\mathbf{p} \in R_\jmath}$ is an indicator function, which equals 1if the pixel p is inside the parallelogram $R_\jmath$ of junction $\jmath$ and equals to 0 otherwise.

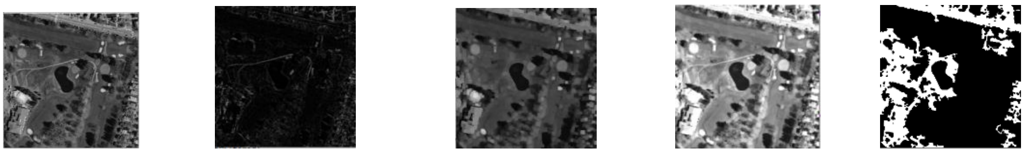
IV EXPERIMENTS AND RESULTS

A.Experimental Data

Massachusetts Buildings Dataset contains 10 images of 1500 x 1500 pixels in the test subset with a spatial resolution of 1 meter. This is a public dataset downloaded from the internet [“https://www.cs.toronto.edu/˜vmnih/data/”] which was used by Huang et al. [4]. To get the best possible results, the required preprocessing was applied to the images.

B. Experiment –I- Extraction of Buildings from remotely sensed Image using Mathematical Morphology based K means clustering algorithm

Morphological operation followed by K means clustering algorithm to extract buildings.



(a)Gray Image (b)TopHat Filtered Image (c)WhiteHat Filtered Image (c)Enhanced Image (e) Building Detection using Morphological K means clustering Result

Fig.1 shows the result obtained using Mathematical Morphology based K means clustering algorithm.

C. Experiment –II - Extraction of Buildings from remotely sensed Image using Fuzzy C means clustering algorithm

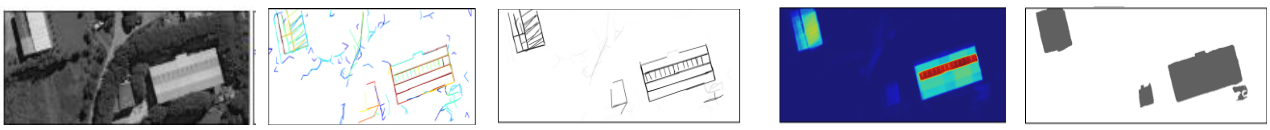
Fuzzy C means clustering was performed to extract buildings from the images in the dataset.

(a)Input Image (b) Ground Truth (c)FCM clustered Output

Fig. 2 shows the result obtained using Fuzzy C means clustering.

D. Experiment –III –Extraction of Buildings from remotely sensed Image using Geometric Saliency

Edge detection considering the geometric saliency was performed to extract the buildings.



(a)Input Image (b)Extracted Junctions (c)computed Geometric Saliency (d)Geometric Building Index (e)Building Detection result

Fig.3 shows the result obtained using Geometric saliency algorithm.

V PERFORMANCE EVALUATION

The extraction accuracies, precision, recall, FScore, completeness, correctness and quality obtained from the three methods of the remotely sensed image is shown in Table 1.The formulae used for performance metrics evaluation were given below, Accuracy = (TP + TN)/ (TP + TN + FP + FN)---- (1.7)

Precision = TP / (TP + FP)---- (1.8)

Recall = TP / (TP + FN)---- (1.9)

F-Measure = (2 * Precision * Recall) / (Precision + Recall)---- (1.10)

Completeness=TP/(TP+FN)---- (1.11)

Correctness=TP/(TP+FP)---- (1.12)

Quality=TP/(TP+FP+FN)----(1.13)

A **FalsePositives(FP)** is an error in binary classification in which a test result incorrectly indicates the presence of a condition such as a building when the building is not present, while a **FalseNegatives(FN)** is the opposite error where the test result incorrectly fails to indicate the presence of a condition when it is present. A **TruePositives(TP)** is the event that the test makes a positive prediction, and the subject has a positive result, In Some cases they don't have the buildings, and the test says they don't ,this denotes **TrueNegatives(TN)**[12].

PERFORMANCE METRICS	Morphological KMEANS	FCM	Geometric saliency
Accuracy	0.6651	0.6422	0.5881
Precision	0.8539	0.8686	0.7837
Recall	0.7387	0.6962	0.6832
Fscore	0.7857	0.7692	0.7299
Complete	0.7387	0.6962	0.6832
Correct	0.8539	0.8686	0.7635
Quality	0.6521	0.627	0.5962

Table 1

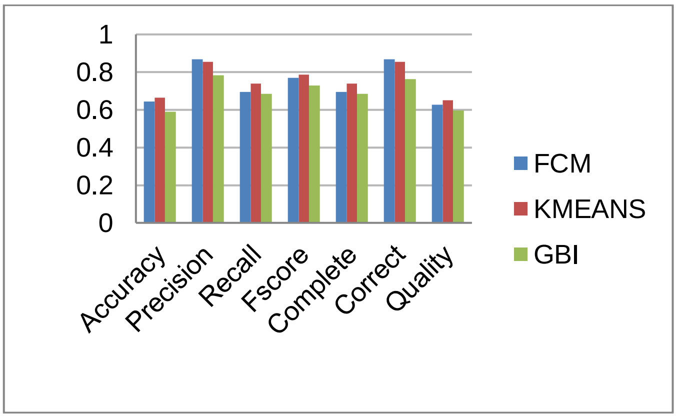


Fig.4 The bar graph connecting the overall performance metrics obtained are plotted.

From the results obtained, it is understood that morphological K means clustering algorithm gave better results when compared to the other two methods.

VI DISCUSSIONS AND CONCLUSION

The buildings from VHR remotely sensed images were extracted using the following algorithms such as,

1. Morphological K means clustering Algorithm,
2. Fuzzy C means Clustering Algorithm and
3. Geometric Saliency Algorithm.

The performances of the algorithms were evaluated. The extraction accuracies obtained using mathematical morphology using K means, Fuzzy C means clustering and geometric saliency are 66%, 64% and 58% respectively. In future, it is proposed to extend the same study using hand crafted features to obtain better building extraction rate.

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