



Recurring High-Resolution Remote Sensing Images for Unsupervised Detection of Built-Up Areas

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Abstract - Given a set of high-resolution remote sensing images covering different scenes an unsupervised approach to simultaneously detect possible built-up areas from them. The motivation behind is that the frequently recurring appearance patterns or repeated textures corresponding to common objects of interest (e.g., built-up areas) in the input image data set can help us discriminate built-up areas from others. With this inspiration, the method consists of two steps. First, we extract a texture feature using Gabor filter and Discrete Wavelet Transform. Given a set of candidate build-up regions, in the second stage, we formulate the problem of build-up area detection as an unsupervised grouping problem. The candidate regions are modeled through texture histogram, and the grouping problems solved by K-Means clustering and graph cuts. The approach outperforms the existing algorithms in terms of detection accuracy.

Index Terms-Two Dimensional (2D) Gabor filter, K-Means, Wavelets Transforms and Graph Cuts

I. INTRODUCTION

With the development of remote sensing technologies, high-resolution remote sensing images have become critical sources of information in diverse field such as geography, cartography, surveillance, city planning, and so on. Among them, monitoring the distribution, growth, and characteristics of built-up area receives a growing number of attentions for it can greatly help local agency to update land maps and draw city plans. In such applications, the basic but important step is to extract built-up regions from the high-resolution remote sensing images.

Remote sensing, which provides inexpensive, synoptic scale data with multi-temporal coverage, has proven to be very useful in land cover mapping, environmental monitoring, and forest and crop inventory. Image classification (i.e., assigning pixels to class labels using some functional mapping) is one of the fundamental analysis techniques used in remote sensing to generate thematic maps. Some of widely used image features for urban classification are texture, edge density, Morphological features etc.

Generally, a built-up [2,3] area represents a vital and highly dynamic environment which is mostly composed of both manmade and natural objects. Because the texture of the scene is distinct from that of the natural scene, major

approaches for built-up area detection are based on texture analysis. Pesaresi and Benediktsson introduce a novel mathematical morphological transformation[1], called differential morphological profile, to extract texture information from the image. In their later work, a build-up area presence index is proposed for built-up area extraction in panchromatic satellite image, which is based on fuzzy rule-based composition of anisotropic texture co-occurrence measures. In recent years, built-up area detection based on local invariant features has revealed promising results. Sirmacek and Unsalan [23] develop a method to detect built-up area and buildings in very high resolution Ikonos satellite images based on scale-invariant feature transform features and graph theory. However, it needs some template building images for training and therefore suffers from a high computing complexity and memory requirement. In their later work, a probabilistic framework to detect buildings in aerial and satellite images depends on local features recognition and their pdf (Probability density function) is detected. However, since it solely depends on local feature for recognition, it can often be too weak of a signal to reliably detect the built-up regions in complex satellite image.

When given a lot of remote sensing images for urban information analysis, we can observe that there are many frequently recurring appearance patterns or repeated textures corresponding to common objects of interest (e.g., built-up area), which is a significant discrimination property to help us discern built-up area from others. Inspired by this idea, we present an un-supervised approach to simultaneously detect built-up regions from multiple high-resolution remote sensing images to our knowledge, the first approach proposed for this problem using such an idea. In our method, we take a built-up region as a common object that appears frequently in the input image data set and use the cues extracted and integrated from multiple images to infer the location of built-up regions. To this end, the proposed approach is divided into two steps. First, we extract a texture feature using Gabor filter, K-Means algorithm and Discrete Wavelet Transform[15-21]. Given a set of candidate build-up regions, in the second stage, formulate the problem of build-up area detection as an unsupervised grouping problem. The candidate regions are modeled through texture histogram, and the grouping problems solved by K-Means clustering and graph cuts. The



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approach outperforms the existing algorithms in terms of detection accuracy.

II. RELATED WORK

When given a lot of remote sensing images for urban information analysis, it is observed that there are many frequently recurring appearance patterns or repeated textures corresponding to common objects of interest for e.g., built-up area, which is a significant discrimination property to help us discern built-up area from others. Inspired by this idea, an unsupervised approach is presented to simultaneously detect built-up regions from multiple high-resolution remote sensing images to our knowledge.

The first approach proposed for this problem using such an idea, a built-up region is taken as a common object that appears frequently in the input image data set and use the cues extracted and integrated from multiple images to infer the location of built-up regions. To this end, the proposed approach is divided into two steps. First, extract a large set of corners from each input image by an improved Harris corner [4, 5, 7, 8] [22] detector. Afterward, incorporate the extracted corners into a likelihood function to locate candidate regions in each input image.

III. PROBLEM DESCRIPTION

After reviewing different approaches used for built-up area detection using multiple high resolution remote sensing images, it is observed that in one of the approach, built-up area is detected manually i.e. detecting built-up area for one by one input image which is a tedious process. Some of the problems with different approaches is that concerns the necessity of looking at range of increasing opening and closing by reconstruction operations which may cause computational burden, they are not much reliable and précised, because we cannot depend only on texture characteristics as we have other characteristics like color and shape. They are not able to detect buildings if the contrast between their roof top and the background is low and also cannot detect some closely placed buildings. Computation Complexity is also high.

IV. MOTIVATION

The motivation behind the idea is that the frequently recurring appearance patterns or repeated textures corresponding to common objects of interest (e.g., built-up areas) in the input image data set can help us discriminate built-up [2,3] areas from others. An unsupervised framework toward simultaneously discovering built-up regions from multiple high-resolution satellite images is presented.

V. PROPOSED TECHNIQUE

The proposed method “Recurring High-Resolution remote sensing Images for Unsupervised Detection of Built-

Up Areas” includes two major components: 1) feature extraction of candidate built up area using Gabor filter[10] and Discrete Wavelet Transform[15-21] and 2) spectrum clustering-using K-Means algorithm[11] and graph-cut-based unsupervised clustering algorithm for the final built-up area detection implemented using MATLAB 2012b [13]. First, it can simultaneously detect built-up regions from multiple images. Second, the entire process is highly automatic and requires no human interaction.

For each image in the input image collection, repeat the aforementioned step to locate candidate urban regions. However, the precise result can be sometimes obtained; there is no guarantee that all extracted candidate built-up regions are such case. Some non-built-up region may be wrongly extracted as well. Upon inspection, to find that most of the false-alarm samples are regions that contain many man-made objects inside them, like airport, harbor, etc. Moreover, utilize a binarization processing to extract candidate built-up regions; false alarms may be extracted from the image which does not contain any built-up regions.

However, from a set of extracted candidate building regions, are observed that there are many frequently recurring appearance patterns or repeated textures corresponding to common objects of interest (e.g., built-up area), which is a significant discrimination property to help us discern built-up area from the false alarms. With this motivation, a method is proposed; an unsupervised grouping algorithm to automatically discover the frequently recurring texture patterns corresponding to built-up areas and further finish the task of built-up area detection. The assumption here is that the “positive” samples (i.e., the ones containing a built-up region) will all have similar features, whereas the “negative” samples are uncorrelated and thus can be modeled by a random mixture of features. Based on the assumption, the proposed unsupervised grouping algorithm consists of three steps: feature extraction and grouping features extracted into clusters, discrete wavelet transform and detecting built-up region.

A. Feature Extraction of Candidate Built-Up Regions

Since the built-up region has unique texture in comparison with a natural area, here, we use the texture feature to describe the built-up region. In our work, the texture feature is obtained by convolving the panchromatic band of each candidate region R with a Gabor filter bank at K scales and S orientations (in the experiment, we set $K=2$) to generate filter responses.

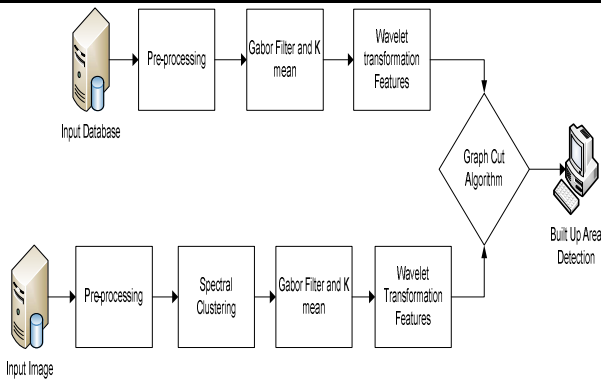


Fig. 5.1: Block Diagram of the Proposed Method

$$V_d(C_i, L(C_i)) = \begin{cases} 1 - \frac{N_{C_i}}{M}, & \text{if } L(C_i)=1 \\ \frac{N_{C_i}}{M}, & \text{if } L(C_i)=0 \end{cases} \quad (3)$$

where M is the total number of the candidate built-up regions and N_{C_i} denotes the region number in cluster C_i . The interaction term V_s measures the proximity of a cluster pair, which has the following form:

$$V(C_i, C_j, L(C_i), L(C_j)) = \begin{cases} 0 & \text{if } L(C_i)=L(C_j) \\ \exp(-K_{x^2}(h(C_i), h(C_j))) & \text{if } L(C_i) \neq L(C_j) \end{cases} \quad (4)$$

Where $h(C_i)$ and $h(C_j)$ denote the mean texture feature histograms corresponding to clusters C_i and C_j , respectively. The graph cut [9] algorithm to minimize the objective function and then classify the clusters to built-up or non-built up region. In the proposed approach, by applying the wavelets transforms method along with Gabor filter and K-Means algorithm, it is expected to improve the quality of an image, obtain high accuracy compared to the existing methods. Firstly, it can simultaneously detect built-up regions from multiple images. Secondly, the entire process is highly automatic and requires no human interaction.

VI. GABOR FILTER

In image processing, a Gabor filters [10], named after Dennis Gabor, is a linear filter used for edge detection. Frequency and orientation representations of Gabor filters are similar to those of the human visual system, and they have been found to be particularly appropriate for texture representation and discrimination. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave.

J. G. Daugman discovered that simple cells in the visual cortex of Mammalian brains can be modeled by Gabor functions. Thus, image analysis by the Gabor functions is similar to perception in the human visual system. Gabor filter is used to examine a small section of a signal at a time, using STFT(Short Time Fourier Transform) a technique called Windowing the signal.

A. Definition

Its impulse response is defined by a sinusoidal wave (a plane wave for 2D Gabor filters) multiplied by a Gaussian function. Because of the multiplication- convolution property (Convolution theorem), the Fourier transform of a Gabor filter's impulse response is the convolution of the Fourier transform of the harmonic function and the Fourier transform of the Gaussian function. The filter has a real and an imaginary component representing orthogonal directions.

B. Properties of Gabor Filter

- A tunable band pass filter

B. Grouping Candidate Built-Up Regions Using K-Means clustering

In this step, K-Means clustering method is used to solve the grouping problem. The resultant filter responses from Gabor filter are aggregated and clustered using the k-means algorithm, which is simple to implement.

C. Finding Discrete Wavelet Transforms Features

After feature extraction in first step and K-Means clustering of built-up region in second step, discrete wavelet transform method [15-21] is applied to get more accurate values of features extracted in both steps, for demonstrating the accuracy of the retrieved image.

D. Detecting Built-Up Regions via Graph Cut

After grouping the candidate regions into several clusters [8], the final step is to identify which clusters are corresponding to the built-up region. Ideally, all the built-up regions would be grouped into one cluster since they belong to the same category. In practice, due to the intra class variations, they may be grouped into one or several clusters. To handle this we formulate the classification problem as a labeling problem, i.e., assigning each cluster $L(C_i)$ as follows:

$$L(C_i) = \begin{cases} 1, & \text{if } C_i \in \text{builtup region} \\ 0, & \text{if } C_i \in \text{non builtup region} \end{cases} \quad (1)$$

The expected that the clusters with larger size are more likely assigned the label of built-up region, which is based on the assumption described previously. At the same time, the clusters with close between-class distance have the same label. To express these desired properties of labeling, we define the cost function of labeling $E(L)$ as

$$E(L) = \sum_i V_d(C_i, L(C_i)) + \sum_{i \neq j} V_s(C_i, C_j, L(C_i), L(C_j)) \quad (2)$$

where the data term measures the possibility of each cluster belonging to a built-up region, which is defined as



- Similar to a STFT or windowed Fourier transforms
- Satisfies the lower-most bound of the time-spectrum resolution (Uncertainty principle)
- It's a multi-scale, multi-resolution filter
- Has selectivity for orientation, spectral bandwidth and spatial extent.
- Has response similar to that of the Human visual cortex (first few layers of brain cells)
- Used in many applications – texture segmentation; iris, face and fingerprint recognition.
- Computational cost often high, due to the necessity of using a large bank of filters in most applications.

VII. K-MEANS CLUSTERING ALGORITHM

K- Means [8,11] is one of the simplest unsupervised learning algorithms that solve the well known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori. The main idea is to define k centers, one for each cluster. These centers should be placed in a cunning way because of different location causes different result. So, the better choice is to place them as much as possible far away from each other.

The next step is to take each point belonging to a given data set and associate it to the nearest center. When no point is pending, the first step is completed and an early group age is done. At this point need to re- calculate k new centroids as bray center of the clusters resulting from the previous step. After these k new centroids, a new binding has to be done between the same data set points and the nearest new center. A loop has been generated. As a result of this loop we may notice that the k centers change their location step by step until no more changes are done or in other words centers do not move any more. Finally, this algorithm aims at minimizing an objective function known as squared error function given by:

$$J(V) = \sum_{i=1}^C \sum_{j=1}^{c_i} (||x_i - y_i||)^2 \quad (5)$$

Where, '|| $x_i - y_i$ ||' is the Euclidean distance between x_i and y_i , ' c_i ' is the number of data points in ith cluster 'c' is the number of cluster centers.

VIII. EXPERIMENTAL RESULTS

Image Format: jpeg, 256 X 256, Color

A. Intermediate Results

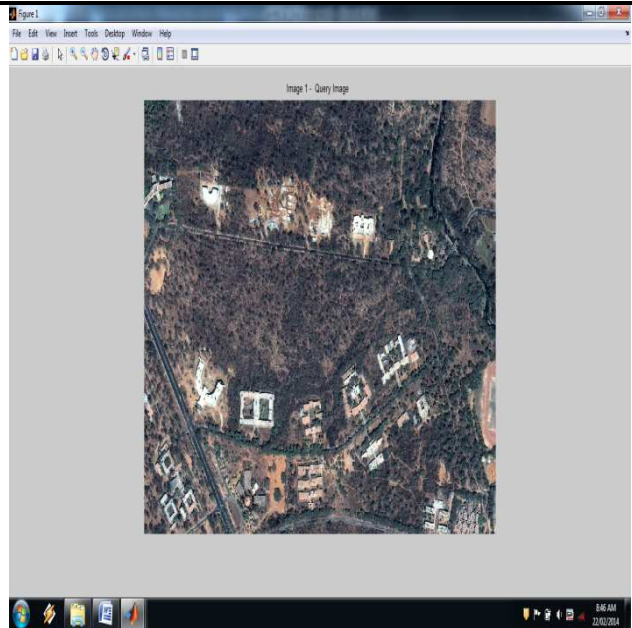


Fig. 8.1: Input image to the pre-processing unit.

Image Format: jpeg, 256 X 256, Monochromatic

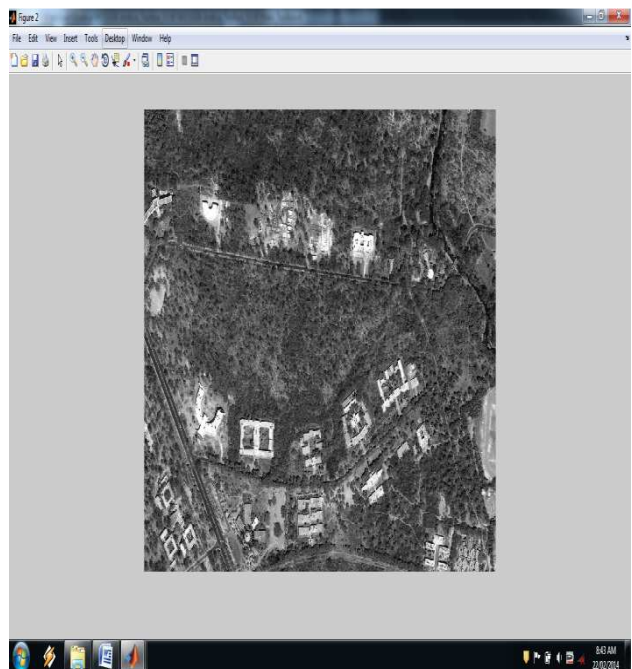


Fig. 8.2: Grey converted image.

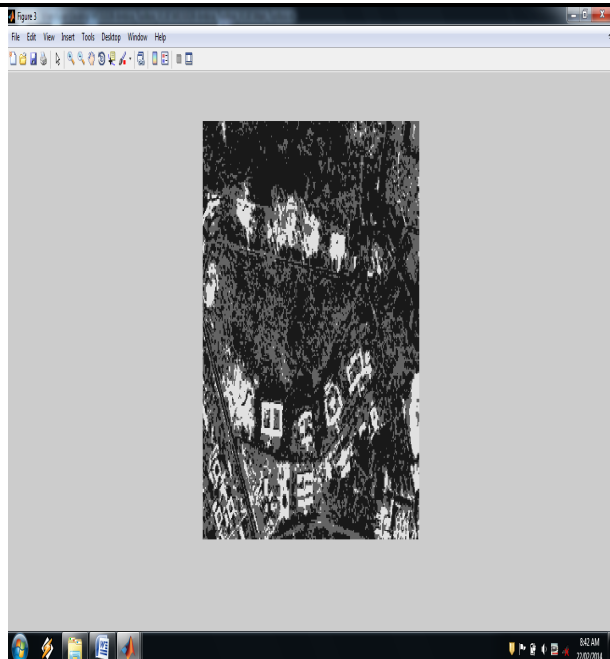


Fig. 8.3: Result of the Gabor convolution and K-Means Clustering.

B. Final Output

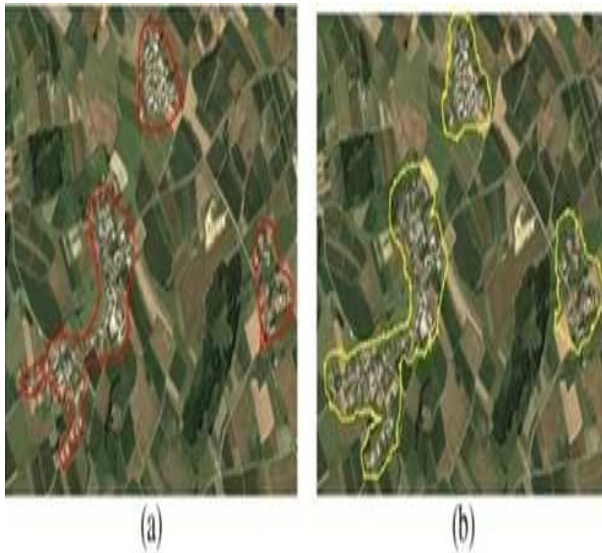


Fig 8.4: Comparison between experimental results and ground truth.

IX. CONCLUSION

Gabor filter, K-Means clustering-and graph-cut-based unsupervised clustering algorithm along with Discrete wavelet transformation is used for the final built-up area detection. Based on this, the proposed approach is expected to demonstrate the following main advantages over the previous

works. First, it could simultaneously detect built-up regions from multiple images, and the performance of built-up area detection can be further improved by exploring the cues drawn. Second, the entire process is highly automatic and requires no human interaction. Work is under process, further, in future enhancement is expected to calculate the PSNR(Peak Signal to Noise Ratio) and MSE(Mean Square Error) values of the original image and the retrieved image, for demonstrating the accuracy of the retrieved image.

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