SHAPE ORIENTED OBJECT BASED CLASSIFICATION OF AERIAL/SATELLITE IMAGES OF URBAN AREAS

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ABSTRACT:

Image segmentation is a crucial step for successful Object Based Image Analysis (OBIA). Instead of dealing with the individual pixels of an image, the object based analyzed image is partitioned into segments. The classification of image segments is a more convenient alternative to the classification of pixels because of the several useful features offered by segments which can lead to a higher classification rate. Among these useful features are the shape features of segments which are highly sensitive to the efficiency of the segmentation step. Both over-segmentation and under-segmentation of images can deteriorate the shapes of the image objects and therefore limit the contribution of the shape features in the classification process. In this research, the importance of shape-derived object features are emphasized in the classification of aerial and satellite images as the shape features are used solely during the classification phase to assess its relevance and importance. The proposed segmentation approach preserves the shapes of the homogenous objects. The presented classification results of the aerial and satellite images based only on shape features show the high importance of shape descriptors in the classification process.

1. INTRODUCTION

The In the recent years, Object Based Image Analysis (OBIA) gained a lot of attention among the geographical mapping applications as an alternative analysis framework that can alleviate the drawbacks associated of pixel based analysis, where the individual pixels are the targets of classification regardless of its neighbourhood. Despite the advantages of pixel based image analysis, this type of analysis suffers from some problems such as sensitivity to variations within objects significantly larger than pixel size (Alpin et al., 2008). Instead of depending on the spatial scale of image pixels, the spatial extent of the objects to be classified is of more importance to the classification task (Flanders et al., 2003; Hay et al., 2006; Platt et al., 2008). Object based classification can noticeably enhance the classification accuracy by alleviating the problem of misclassifying individual pixels (Platt et al., 2008, Alpin et al., 1999). Moreover, OBIA uses objects as targets for classification which introduces more semantic attributes to assist for classification such as shape attributes. It also enables easy integration with vectored GIS data typically used in the relevant applications. A lot of research effort has been offered to apply OBIA framework on the typical geographical classification problems with notable success and potential opportunities for further improvements.

As a very critical step in OBIA, image segmentation methodology should be carefully chosen to guarantee efficient results. Various theories and assumptions have been utilized to develop robust image segmentation techniques to serve a wide variety of applications. Region growing is one of the most popular techniques for image segmentation that have been implemented with a lot of variations. These methods typically group a collection of pixels with similar properties to form uniform regions. First, seed pixels should be found to help as start points for each region. The neighbour pixels of this seeds are tested against similarity metric to decide if they should be merged into this region. The new merged pixels serve as new seed pixels to continue the above process until no more pixels that satisfy the condition can be included. The variations of this algorithm represent the different choices of the different stages of the algorithm such as the seed pixels selection procedure, the similarity metric used, and the used rule for stopping the growth process. (Tang, 2010) is an example of region growing algorithms where the selection of seed points is based on watershed algorithm. Some approaches adopt a split and merge technique to reduce the computational burden and avoid processing of the homogenous areas of the image. As an example, (Chen et al., 1979) used a quadratic picture tree with N levels of the picture for implementing a split and merge algorithm. Some approaches handled the image segmentation problem as a clustering task in which the image pixels are clustered according to their features making use of different well established clustering algorithms such as k-means algorithm (Ray et al., 1999), fuzzy c-means (Chaabane et al., 2008), and neural networks (Dong et al., 2005).

Based on the adopted image segmentation technique, the objects extracted from the image exhibit the properties of the underlying segmentation assumption. Vast amount of OBIA research effort adopts segmentation methodologies that partition images into objects of a specific spatial scale that match the scale of interest. (Baatz et al., 2000) presented an optimization approach for high quality multi-scale image segmentation in which the object size is adaptable to agree with the spatial scale of the intended structures to be analyzed. Despite the successful application of such segmentation methodologies, these techniques assume that classification targets are of the same spatial scale which is not always the case. Many applications typically target different classes of different spatial scales such as roads, building and vegetation. Segmenting images into objects of the same scale will either over-segment the larger classes such as roads, or under-segment the smaller classes such as small vegetation areas with other areas. Both over-segmentation and under-segmentation of objects do not maintain the original shape of the object and therefore limit the opportunity of using the important shape-derived object descriptors such as object area, smooth boundaries, and eccentricity.

In this research, the importance of shape-derived object descriptors is emphasized in the classification of aerial and satellite images. Primitive shape descriptors such as area are used solely during the classification phase to assess the relevance and importance of the shape descriptors. The proposed segmentation approach preserves the shapes of the different objects scales. The presented classification results of the aerial and satellite images based only on primitive shape descriptors show the high importance of shape descriptors in the classification process.

2. METHODOLOGY

The high variation of spectral characteristics within the same object complicates the use of similarity threshold in region growing algorithms and can lead to over segmentation, especially in highly detailed aerial images. The proposed segmentation algorithm uses image smoothing filters to overcome the high variation within the same object. As the traditional smoothing filters such as Gaussian filters tend to remove the image edges, bilateral filtering is used to preserve edges while smoothing the image within the regions of comparable spectral values. As a preliminary step, a bilateral smoothing filter is conducted as follows

$$BF[I]_{\mathbf{p}} = \frac{1}{W_{\mathbf{p}}} \sum_{\mathbf{q} \in S} G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)\, G_{\sigma_r}(|I_{\mathbf{p}} - I_{\mathbf{q}}|)\, I_{\mathbf{q}} \qquad (1)$$

where $BF[I]_p$ is the filtered value at point p
W_p is a weighting factor
S is the neighbourhood of point p
$G_{\sigma s}$, $G_{\sigma r}$ are Gaussian functions
I_p is the image value at point p
I_q is the image value at point q.

Figure 1. An image of an urban area

This bilateral filtering step is repeated until the overall change of the image falls under a threshold. A 4-connected neighborhood region growing segmentation is conducted on the filtered image based on the color difference of the neighbor pixels. The perceptually uniform L*a*b* color space has been used during the region growing procedure. The shape descriptors such as area are calculated for the previously extracted objects.

Figure 2. Segmentation result of the proposed approach

Based on the shape descriptors, the extracted objects are classified as roads, buildings, and vegetation. As the roads typically exhibit large connected areas that exceed areas of buildings, objects that exceed the largest expected building size are classified as roads. On the other hand, vegetation tends to have high color variation that result in smaller extracted objects. Objects under minimum expected area of a building are classified as vegetation. Objects of areas between the two thresholds are classified as buildings. More spectral and textural features can be easily introduced into the classification step to enhance the results.

Only shape descriptors are employed during the classification to assess its relevance and significance in the classification of such classes. Even without the incorporation of the non-shape descriptors, the results based on only the shape descriptors show the significance of the shape descriptors.

Figure 1 shows a sample satellite image of an urban area; Figure 2 shows the segmentation result of the presented approach. The segmentation results exhibit objects of different scales and the shapes of the homogenous objects such as buildings and roads maintain its entire shape while the vegetation class is segmented into small size segments.

Figure 3.a segmentation results with small scale

On the other hand, segmentation algorithms that use both spectral characteristics and segment scale to force the extracted segments to be of nearly equal scale exhibit either over-segmentation of large classes such as roads and buildings and sacrifices preserving of shape descriptors of these objects as depicted in Figure 3.a or exhibit under-segmentation of smaller classes joining them into larger objects as shown in Figure 3.b where most of cars are merged with their neighbors into larger objects and also small isolated road parts are merged with buildings to fulfil the segment scale constraint.

Figure 3.b segmentation results with large scale

3. RESULTS

To assess the proposed approach and the significance of shape descriptors in the classification process, images of urban areas in Calgary city with different resolutions have been tested. The images have been segmented using the above-mentioned approach and the size of the extracted segments has been used solely in the classification process.

Figure 4.a Classified vegetation

Figure 4.a depicts the classified vegetation class of the scene in Figure 1 with producer accuracy of 98% and user accuracy of 61% due to misclassification of non-vegetation areas such as cars and small building details that can be easily corrected using the spectral attributes of the these objects.

Figure 4.b depicts the classified roads class of the scene in Figure 1 with producer accuracy of 81% and user accuracy of 92% where small parts of buildings are misclassified as roads and a small part of the road in the upper left corner is misclassified because it was represented as a small separate segment that is disconnected from the rest of road segment.

Figure 4.b Classified roads

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Figure 5 shows a sample ortho-rectified aerial image of an urban area; Figure 6 shows the segmentation result of the proposed approach. The segmentation results exhibit objects of different scales and the shapes of the homogenous objects such as buildings and roads maintain its entire shape while vegetation areas exhibit segmented objects with small size.

Figure 7.a depicts the classified vegetation class of the scene in Figure 5 with producer accuracy of 87% and user accuracy of 84% where few misclassifications of non-vegetation areas are noticed that can be easily corrected using the spectral attributes of the these objects and also some vegetation areas are missed due to their relatively large areas, these missing parts can be corrected using the boundary shape descriptors as they typically exhibit non smooth boundaries.

Figure 7.b shows the classified roads class of the scene in Figure 5 with producer accuracy of 91% and user accuracy of 79% where only small parts of roads are missing and few building tops was misclassified as a road because the high similarity between its spectral attribute and that of the roads. The small areas inside the roads classes belong to vehicles class and can be clearly classified if its neighborhood is considered in the classification process.

Figure 7.c illustrates the classified buildings class of the scene in Figure 5 with producer accuracy of 72% and user accuracy of 70% where most of building are correctly classified with accurate boundaries and some of the vegetation areas are misclassified as buildings due to their large areas and can be corrected using the boundary shape descriptors as they typically exhibit non smooth boundaries. Few buildings were missing due to the high similarity between its spectral attribute and that of the roads.

Figure 5 Ortho-rectified aerial image of an urban area

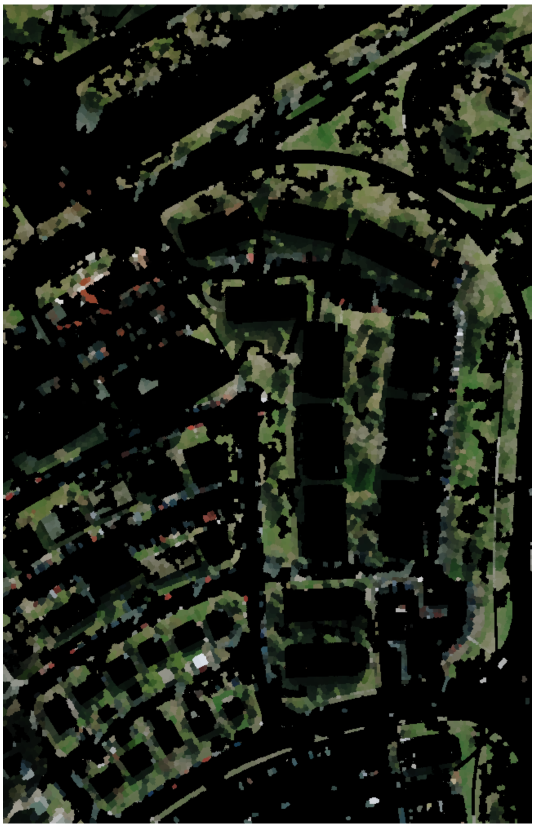

Figure 7.a Classified vegetation

Figure 6 Segmentation result of the proposed approach

Figure 7.b Classified roads

Figure 7.c Classified buildings

4. CONCLUSIONS

In this research, a segmentation approach has been presented that preserves the image edges and also the shape of its main objects. In contrary to the widely used assumptions of similar spatial scale of segmented objects, the presented approach produces objects of different scales and hence avoids the over-segmentation and under-segmentation typically encountered when similar object scale is assumed. The shape preserving during the segmentation phase is exploited to emphasize the significance of the shape descriptors of objects in the classification phase. Sample images of different resolutions have been classified using only the segment area as a shape descriptor. The classification results, with this single primitive descriptor, prove the importance of shape descriptors and encourage the adoption of shape preserving segmentation techniques. Further inclusion of more shape descriptors such as boundaries smoothness can be used to enhance the classification results significantly.

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