An Optimized Technique of Multiresolution Segmentation for Glacier Multispectral Imagery

Shikha Sharda, Mohit Srivastava

Abstract - Object-Based Image Analysis has gained widespread popularity with the increase in the spatial resolution of imaging sensors. The extraction of meaningful information from remotely sensed imagery is a challenging task. Image segmentation is an essential step in object-based classification. It is a salient tool in image processing that simplifies the representation of remotely sensed data that is more meaningful and easier to analyze. This paper introduced an automatic approach for the selection of multiresolution segmentation parameters for mapping glacier snow/ice. It utilized the spectral information associated with multispectral bands for defining color and an object-based compactness feature for defining the compactness criterion. The potential of Local Variance has been used for estimating scale parameter. The proposed technique has produced optimum segments in a single iteration unlike the Trial & Error method and reduced the processing time.

Keywords: Multiresolution Segmentation, Local Variance, NDSI, Object-Based Feature

I. INTRODUCTION

With the significant improvement in spatial resolution of satellite systems, the traditional pixel-based methods are no longer useful to extract ground objects from medium and high-resolution satellite imagery. As in low-resolution imagery, a single pixel often includes desired features of the area under observation. For medium and high-resolution imagery, a single pixel no longer covers the features of the target for classification. In that case, pixel-based image analysis techniques can’t be used for information extraction. Therefore, researchers started refocusing on the group of pixels rather than on a single pixel. OBIA technique is the best alternative approach for extracting desired objects from medium and high-resolution images.

OBIA based classification techniques are applied in various fields such as monitoring of landscape areas; the monitoring of glacier ice coverage, glacier lake, debris etc [1], [2]. In OBIA, the foremost and crucial step is the segmentation process that forms segments by merging homogenous pixels [3], [4]. The segmentation technique is broadly classified into three categories namely edge-based techniques, point-based techniques and region-based [5].

eCognition Developer software provides region-based multiresolution segmentation technique that is widely used for delineating glacier based on three user-defined parameters like scale, shape, and compactness.

The selection of the most suitable parameters for image segmentation is very tricky. It depends mainly on trial and error method [6]. To help the user with a selection of these parameters, the unsupervised methods like Estimation of Scale Parameter (ESP) for a single band and ESP-2 for multiband images based on the Local Variance (LV) were introduced [7], [8]. An automatic scale selection tool was applied on a single layer that contains SRTM data [9]. Only the elevation information was considered to classify the topography into different categories: high/ low mountains, low hills, high/low plains and tableland high hills at three hierarchy levels automatically generated by scale estimation tool. The shape criterion was set to zero, no shape optimization was done. Later, L. Dragut successfully introduced a new scale parameterization tool to segment the multiple layers [8]. This tool was tested on very high-resolution images comprising three different regions: temporary settlement area, mixed residential/ industrial/agriculture area and mixed riparian/ agriculture area. For segmentation, the default values of shape and compactness parameters were used. However, the above-mentioned work included scale optimization only. Considering the importance of segmentation in GEOBIA, there is a need to improve the multiresolution segmentation parameter selection procedure. For glacier ice/snow mapping, the shape parameter plays the least role; therefore, color information associated with bands was utilized.

This paper focused on making the selection of segmentation parameters fully automatic for segmenting glacier surface through eCognition software. In this work, a new approach for optimizing the compactness parameter making parameters selection technique fully automatic to reduce the processing speed has been incorporated with the existing ESP-2 technique. Optimal segmentation results have been observed when an object-based compactness feature; a customized object feature that employs spectral information linked to Green and Shortwave Infrared (SWIR) bands were used.

II. STUDY AREA

The proposed approach was tested on Landsat 4-5 Thematic Mapper (TM) imagery at 10 different locations as shown in Fig. 1 in Himalayan Siachen glacier region that is located within the coordinate 35.5°N 77°E.

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Normalized Difference Snow Index (NDSI) has been used. This ratio extracts the snow/ice area from the rest part of the glacier.

The measure of shape compactness feature is used to represent the degree to which shape is compact. The compactness is acknowledged as the alluring property of the shape that defines the homogenous region sharing common attributes and properties. A compact polygon has its vertices equidistant from the centroid. It can be quantified by comparing its area with an ideal shape like a circle (having maximum compactness). Therefore, polygon compactness is computed by perimeter and area, as described below:

\[
C_{IPQ} = \frac{4 \pi \text{Area}}{\text{Perimeter}^2}
\]

Feature value range: [0; 1 for a circle]. Higher the value of \(C_{IPQ}\), the more compact is the shape. A circle is considered to be the most compact shape having a compactness value of 1. It is appropriate in estimating the compactness index for multispectral data. The existing trial and error method of finding optimal compactness parameter is compared with this Iso-perimetric Quotient measure of computing compactness.

### III. METHODOLOGY

The multiresolution image segmentation algorithm was used to segment the Landsat imagery into homogeneous regions. This approach is a bottom-up region-merging technique that considers each pixel as a separate object and subsequently, merges image objects to form bigger objects based on homogeneity criteria that describe the degree of similarity between adjacent image objects. A customized tool ESP2 has been used within the eCognition Developer Software suite for identifying a suitable range of scale parameters for segmentation on glacier imagery. This tool automatically segments the image with user-defined increment value for scale parameter and generates three hierarchy levels. This methodology measures Local Variance (LV) over the entire scene. The automatic selection of scale parameter is based on a threshold calculated at a point where the LV value at the current level (LVn) is equal to or lower than the LV value generated at the previous level (LVn+1). Then the scale parameter value of layer n-1 is then considered as an optimal parameter for segmentation.

In addition to scale, shape and color/intensity is another important parameter to perform proper segmentation. Shape feature plays an important role in extracting structures like buildings, roads, etc. These structures have a well-defined shape. The ice doesn’t have a definite shape, but it differs from neighboring objects with its pixel color/intensity information. Therefore, in addition to optimization of scale parameter through the ESP-2 tool, features related to intensity values of pixels have been included during segmentation. To monitor glacial ice cover, a customized arithmetic feature Normalized Difference Snow Index (NDSI) has been used.

\[
NDSI = \frac{TM_{Green} - TM_{SWIR1}}{TM_{Green} + TM_{SWIR1}}
\]

NDSI utilizes the spectral information associated with Green and Shortwave Infrared (SWIR1) Layers of multispectral satellite imagery. This ratio extracts the snow/ice area from the rest part of the glacier.

Based on visual assessment, the best segments were obtained for the combination of SP = 30 and compactness = 0.8 (Fig. 3(g)).

### IV. RESULTS

This paper aims at optimizing the compactness parameter selection procedure for multiresolution segmentation. Firstly, the trial and error technique of finding optimal compactness parameter has been performed on the input data sets constituting ten test regions. The segmentation results for “Region 1” at different compactness parameter by keeping shape parameter constant have been discussed in detail. Table I shows the corresponding scale parameters and number of objects formed at different compactness values. Level L1 being the finest object-level has been considered that forms the segments similar to the real world. The tool automatically updates the Scale Parameter (SP) for different values of the compactness parameter. The SP is computed based on LV that can be graphically presented through LV graph where objects were well defined in a meaningful manner. Fig. 2(a) shows the SP value at which an optimum segmentation result was obtained in case of trial and error. The segments (homogenous region) formed by changing the compactness value from 0.2 to 0.9 are shown in Fig. 3. The segments formed for different compactness parameter resulted in inappropriate segments. The problem of over-segmentation and under segmentation occurred that is represented by “white” and “yellow” circle respectively. Based on visual assessment, the best segments were obtained for the combination of SP = 30 and compactness = 0.8 (Fig. 3(g)).
Table - I: Summaries the segmentation results at different compactness value for “Region 1”.

<table>
<thead>
<tr>
<th>Test</th>
<th>Hierarchy Level</th>
<th>Scale</th>
<th>Shape</th>
<th>Compactness</th>
<th>Number of objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>L1</td>
<td>22</td>
<td>0.1</td>
<td>0.2</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>72</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>272</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T2</td>
<td>L1</td>
<td>18</td>
<td>0.1</td>
<td>0.3</td>
<td>177</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>88</td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>288</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T3</td>
<td>L1</td>
<td>29</td>
<td>0.1</td>
<td>0.4</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>69</td>
<td></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>269</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T4</td>
<td>L1</td>
<td>24</td>
<td>0.1</td>
<td>0.5</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>104</td>
<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>204</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T5</td>
<td>L1</td>
<td>25</td>
<td>0.1</td>
<td>0.6</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>95</td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>395</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>T6</td>
<td>L1</td>
<td>30</td>
<td>0.1</td>
<td>0.7</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>100</td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>200</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T7</td>
<td>L1</td>
<td>30</td>
<td>0.1</td>
<td>0.8</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>90</td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>190</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>T8</td>
<td>L1</td>
<td>21</td>
<td>0.1</td>
<td>0.9</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>71</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>271</td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

This technique of finding optimal compactness parameter is a very time-consuming task. Therefore, an effort was made to optimize the selection procedure of the compactness parameter to automate the process. The object-based features i.e. NDSI and Iso-perimetric quotient were used to define color and compactness parameter that successfully obtained the optimum segments at SP = 45 in a single iteration as shown in Table II (Refer Region 1). Fig. 2(b) shows the SP value at which an optimum segmentation result was obtained by the proposed method.

The remaining nine regions were segmented with proposed and trial & error technique.
In the trial and error technique, the shape parameter was kept constant at 0.1 and different combinations of shape and compactness parameters have been tried to get optimum segments. Later, the proposed technique was used to get optimal segmentation results in a single iteration. NDSI is a standardized ratio that takes advantage of a unique signature to delineate snow/ice from the surrounding objects. In addition to color information, compactness was considered to be an important factor in defining meaningful homogenous objects that share common attributes and properties. The corresponding optimal segmentation results were summarized in Table 2. As a result, Ice/Snow coverage area has been properly segmented in a single iteration. Based on the operator’s visual assessment, an optimal segmentation has been achieved that minimized over-segmentation as well as under-segmentation. Therefore, the proposed technique is better as compared to traditional trial and error technique as it required less computational time and shown acceptable results.

![Segmentation Results](image)

**Fig. 3.** Detail of segmentation results for “Region 1”: (a)-(h) at different combinations of scale and compactness parameters.

**Table – II:** Summarizes the optimal segmentation results for different regions obtained from Trial & Error and Proposed Technique.

<table>
<thead>
<tr>
<th>Region</th>
<th>Trial and Error Technique (Shape = 0.1)</th>
<th>Proposed Technique (NDSI &amp; Iso-Perimetric Quotient for Compactness)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>SP: 30, Compactness: 0.8</td>
<td>SP: 45</td>
</tr>
<tr>
<td></td>
<td>SP: 26, Compactness: 0.3</td>
<td>SP: 49</td>
</tr>
</tbody>
</table>

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3. SP: 29 Comp: 0.6
SP: 45

4. SP: 25 Comp: 0.5
SP: 31

5. SP: 27 Comp: 0.2
SP: 37.2

6. SP: 25 Comp: 0.2
SP: 25

7. SP: 29 Comp: 0.9
SP: 40
V. CONCLUSION

The selection of appropriate segmentation parameters was dependent on the Trial and Error approach. A lot of time was consumed in finding the best combination of the three user-defined parameters (Scale, Shape, and Compactness) to get the effective segmentation result. An effort has been made to fully automate the selection procedure of segmentation parameters. The Object-based features namely NDSI and IPQ, were used to calculate the color and compactness parameters respectively. These features have reduced the computational complexity and increases the effectiveness of segmentation results. Scale parameter was estimated based on LV by using the ESP2 tool within the eCognition software. Based on visual interpretation, the proposed approach appears to produce the generalized results and a better partition of the glacier surface from the land classification perspective in a single iteration. This automatic parameterizing of segmentation parameters has reduced the execution time and hence, speed up the whole process of multiresolution segmentation.

REFERENCES


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