MULTI-SCALE IMAGE ANALYSIS OF SATELLITE DATA USING PERCEPTUAL GROUPING

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1. INTRODUCTION

A meaningful image segmentation groups the pixels into disjoint regions that consist of uniform components. Facing absence of contextual knowledge, the only alternative which can enrich our knowledge concerning the significance of our segmented groups is the creation of a hierarchy guided by the knowledge which emerges from the superficial and deep image structure [1]. In the present work, we deal with information which can be retrieved from the superficial structure of the image and we study hierarchical methods based on a region-based approach, wherein the initial pixel grouping is guided by the principles of the watershed analysis [2]. Hierarchical feature representation through multi-scale segmentation offers new possibilities in object-oriented and multi-scale image analysis of satellite images [3, 4]. Our objective, in this work, is to create a hierarchy among the gradient watersheds which preserves the topology of the initial watershed lines and extracts homogeneous objects of a larger scale. The proposed method segments an image into regions, which are then merged using an innovative saliency-driven perceptual organization approach. Moreover, we propose a criterion which allows automatically extracting the best segmentation level from the obtained hierarchical levels.

2. METHODOLOGY

The input multi-spectral image is segmented using the watershed transform. To apply the watershed, the gradient of the multi-spectral image is obtained by combining, using the approach of [5], the gradients of the texture (orientations) and the gradients of the spectral bands. This approach allows obtaining a final gradient capturing all perceptual edges in the input image. The output of the watershed segmentation is a Region Adjacency Graph (RAG), $G(P^0, E)$. The nodes, $P^0 = \{r_1^0, r_2^0, ..., r_{m_0}^0\}$ are the set of regions; the set of arcs E, connecting the nodes, are the the boundaries between neighboring regions. Each region is represented by its average feature, which in this paper is the Lab color, $(\mu_L(r_i^0), \mu_a(r_i^0), \mu_b(r_i^0))$.

Our main goal here, is to create a hierarchy among the gradient watersheds which preserves the topology of the initial watershed lines and extracts homogeneous objects of a larger scale. The *waterfall* algorithm [2] is used here for producing a nested hierarchy of partitions, $P^h = \{r_1^h, r_2^h, ..., r_{m_h}^h\}; h = 1, \cdots n$, which preserves the inclusion relationship $P^h \supseteq P^{h-1}$, implying that each atom of the set P^h is a disjoint union of atoms from the set P^{h-1}. For successively creating hierarchical partitions, the waterfall algorithm removes from the current partition (hierarchical level) all the boundaries completely surrounded by higher boundaries. Thus, the saliency of a boundary is measured with respect to its neighborhood. The iteration of the waterfall algorithm ends with a partition of only one region.

Considering Gestalt factors, such as proximity, similarity and convexity, in our implementation of the waterfall, the saliency measure of a boundary is based on a collection of energy functions used to characterize desired single-region properties and pair-wise region properties. The single region properties include region area, region convexity, region compactness and color variances within the region. The pair-wise properties include color mean differences between two regions and edge strength.

3. SEGMENTATION QUALITY MEASURE

In most hierarchical segmentation problems, a researcher is faced with the dilemma of selecting the number of segments or regions in the final solution [6, 7]. A user may select visually and qualitatively, the hierarchical level at which the resulting segmentation is acceptable. Conversely, various empirical evaluation measures have been proposed to judge segmentation results quantitatively [8, 9]. These methods rely on segmentation quality measures such as intra-region uniformity [10], region shape [11], and inter-region dissimilarity of the segmented image. These characteristics serve as basis to design goodness measures for satisfying the human intuition on an ”ideal” segmentation. When applied to the results of hierarchical segmentation algorithms, these evaluation criteria are sometimes referred to as stopping rules.

In the current work, we introduce an innovative hierarchical segmentation approach with automatic 'best segmentation level' selection based on a quantification of the segmentation quality for each level of the hierarchical tree via an evaluation criterion. The proposed criterion for a hierarchical level (k) denoted by $CH^{(k)}$, is based on two characteristics: (i) the intra-segment color homogeneity, and (ii) the inter-segment separability. Formally, $CH^{(k)}$is defined as:

$$CH^{(k)} = \frac{\sum_{j=1}^{N} C_j/(N-1)}{\sum_{j=1}^{N} H_j/(S_I - N)} \quad (1)$$

where, for a segmented image I, S_I denotes the area (as measured by the number of pixels) of the full image, N is the number of regions in the segmented image, H_j is the homogeneity measure of the region j and C_j is an inter-region separability measure, interpreted as a color difference between regions.

4. CONCLUSIONS

This work reports a novel region-based hierarchical image representation. The proposed approach involves a multi-scale concept allowing the segmentation of meaningful regions at the corresponding scale, using the waterfall algorithm. Unlike existing models, the proposed approach do not require any scale parameter. Experimental results demonstrated the usefulness of the approach.

5. REFERENCES

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