FINDING COMPOUND STRUCTURES IN IMAGES USING IMAGE SEGMENTATION AND GRAPH-BASED KNOWLEDGE DISCOVERY

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The increase in the amount of available high-resolution remotely sensed data is subsequently causing the augmentation of applications that aim for automatic information extraction and knowledge discovery. One interesting way of enabling high-level understanding about the image content is to identify the significant image regions that are internally heterogeneous. These image regions are comprised of more than one object of diverse types and hence can be also referred as compound objects. In comparison to the single object detection, the studies that aim to detect the compound objects are not encountered frequently in the literature. Several segmentation algorithms have been proposed to partition the image into homogeneous regions; however, in order to obtain the meaningful regions that are internally heterogeneous further exploration must be performed. Besides, detecting the exact boundaries of a single object may not always be feasible due to the color variation within the object, the texture it may consist of, and the noise that can often be present. Moreover, as mentioned in [1], in some cases there may not be enough detail for understanding the image at a single-object level.

Several attempts have been made for detecting compound objects of predefined types. For example, the study illustrated in [2] performs the detection of harbors and golf courses by employing textural information. It learns the texture-motif model that corresponds to spatially recurrent patterns of image primitives for each compound object from a set of training examples and uses the learnt model for object detection. [3] detects and classifies the building groups as organized and unorganized by constructing and clustering the graph whose vertices correspond to buildings. Another example is the procedure proposed in [4]. It discovers the built-up areas in high-resolution SAR images by using the local autocorrelation and mathematical morphology.

In this work, we propose a generic method for discovering interesting and significant compound objects regardless of their types. The method translates image segmentation into a relational graph and applies a graph-based knowledge discovery algorithm to find the interesting and repeating substructures that correspond to compound objects. The first step in the algorithm is image segmentation where the regions found correspond to primitive objects that have relatively uniform spectral content. The quality of this initial image segmentation strongly influences the effectiveness of the following object-based analysis. We use the Recursive Hierarchical Segmentation (RHSEG) algorithm [5] for this segmentation step. RHSEG is a promising choice because of three key factors: (i) the high spatial fidelity of image segmentations produced by RHSEG, (ii) automatic grouping of the spatially connected region objects into region classes, and (iii) automatic production of a hierarchical set of segmentations.

The next step is the translation of this segmentation into a relational graph structure. In the constructed graph, the nodes represent the image regions and the edges correspond to the “relationship degree” between these regions. Two key pieces of information that appear to be important for modeling the relationship degree are the size of the region objects and the nature of the region object neighbor relationship. While utilization of region size information is relatively straightforward, the region object neighbor relationship requires some further exploration. It is common to use an unweighted graph and let the edges represent only the spatial adjacency [6]. However, by using this approach we may lose the detailed contextual information and the results may also suffer from the errors in segmentation (especially small details in urban areas in very high-resolution imagery such as Ikonos or Quickbird). An alternative is to set a fixed threshold for distance and connect the regions that are closer than the threshold with an edge. However, since this approach is scale dependent, it can often lead to the addition of unrelated neighbors in some cases while still losing some important neighbor information in some other cases. Moreover, the space proximity is not sufficient to thoroughly capture the relationship information; therefore, our objective is to concentrate on the proximity in the relationship as well.

In this paper, we assume that the region objects that appear together frequently in the image can be considered as strongly related. This relation is modeled using the transition frequencies between neighboring regions in the image. In order to incorporate the region transition frequencies together with region types and sizes, we represent each inter-region transition by a point in a multidimensional space, where the space dimensions correspond to the spectral (RGB values) and scale (size) features of two regions (total of eight dimensions) involved in the transition. The regions with similar content are expected to be similar in terms of their spectral features and sizes; thus, we assume that the transitions that involve two similar region pairs fall close to each other in the spatial co-occurrence space. This space is modeled by a Parzen window-based non-parametric probability distribution, and the modes (local maxima) found from the probability density function correspond to the accumulation of points in the space. The points that constitute these dense regions stand for the most frequently occurring and hence the most important transitions.

By examining the location of each transition point in the spatial co-occurrence space, we calculate the relationship degree between the adjacent regions, and based on this value assign the weights to the corresponding graph edge. By analyzing the edge weights, the graph is clustered to find the subgraphs. These subgraphs are composed of nodes with corresponding edges that have high weights modeling frequent spatial co-occurrence. Furthermore, since the relational graph encodes the full spatial information in the image, the subgraphs also contain neighborhood and proximity information among multiple region objects. Therefore, the subgraph nodes correspond to the region objects that occur together in a high-level compound object structure. Early results on Ikonos images showed that the subgraphs obtained by clustering the graph described in this paper correspond to different high-level urban structures with heterogeneous content such as high-density residential areas, low-density residential areas, parks, fields, and different types of industrial areas.

1. REFERENCES

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