Combining Segmentation and Classification Techniques for Fuzzy Knowledge-based Semantic Image Annotation

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ABSTRACT

In this demo, a system for the semantic annotation of images is presented. The proposed knowledge-assisted analysis architecture comprises algorithms that perform semantic image segmentation, region-level classification and fuzzy reasoning; hence, it constitutes a complete solution to the problem of image annotation based on semantic criteria.

1. INTRODUCTION

Recent advances in the hardware technology have led to a tremendous increase of the total amount of digital images generated everyday. This has triggered intense research efforts towards the development of sophisticated and user-friendly systems that will facilitate the average user in tasks like image indexing, search and retrieval based on semantic criteria. In this demo, a knowledge-assisted semantic image annotation system is presented. The proposed architecture, which is depicted in Fig. 1, incorporates methods for semantic-aware image segmentation, object detection and recognition, as well as methods for the detection of abstract concepts that can only be inferred using higher-level knowledge.

2. SEMANTIC IMAGE SEGMENTATION

Under the proposed approach, a variation of the traditional Recursive Shortest Spanning Tree (RSST) technique is used, in order to segment the image in a set of more semantically coherent regions. It is based on the fundamental idea that neighbor regions, which are assigned the same semantic concept by particular feature detectors, should be merged, since they define a single object [1]. In particular, this variation, called semantic RSST (S-RSST), follows in principle the algorithmic definition of the traditional RSST, though a few adjustments were added, in order to improve the usual over-segmentation results by incorporating region labeling in the segmentation process. The modification of the traditional algorithm to S-RSST relies on the redefinition of the following two criteria: (a) The dissimilarity criterion between two adjacent regions, which incorporates semantic region labeling together with low-level features information, and (b) the termination criterion. The latter is adaptively calculated at the beginning of the algorithm.

3. REGION CLASSIFICATION

3.1 Support Vector Machine-based Classification

Support Vector Machines (SVMs) have been widely used in semantic image analysis tasks due to their reported generalization ability and their efficiency in solving high-dimensionality pattern recognition problems. In the proposed framework, they are utilized in order to identify the actual objects that are depicted in the image. Specifically, SVMs are employed for performing the association of the computed image regions to one of a set of pre-defined high-level semantic concepts, based on low-level image features. A SVM structure[1] is developed, where an individual SVM is introduced for every defined concept, to detect the corresponding instances. At the evaluation stage, each SVM returns for every image segment a numerical value in the range $[0, 1]$. This value denotes the degree of confidence, to which the corresponding region is assigned to the concept associated with the particular SVM [4].

3.2 Bio-Inspired Classifier

Similarly to the SVM-based classifier, an individual Self Organizing Map (SOM) network is utilized to detect instances of the supported high-level semantic concepts, based on the estimated low-level image descriptions. The objective of

[1]http://mklab.iti.gr/svmcf

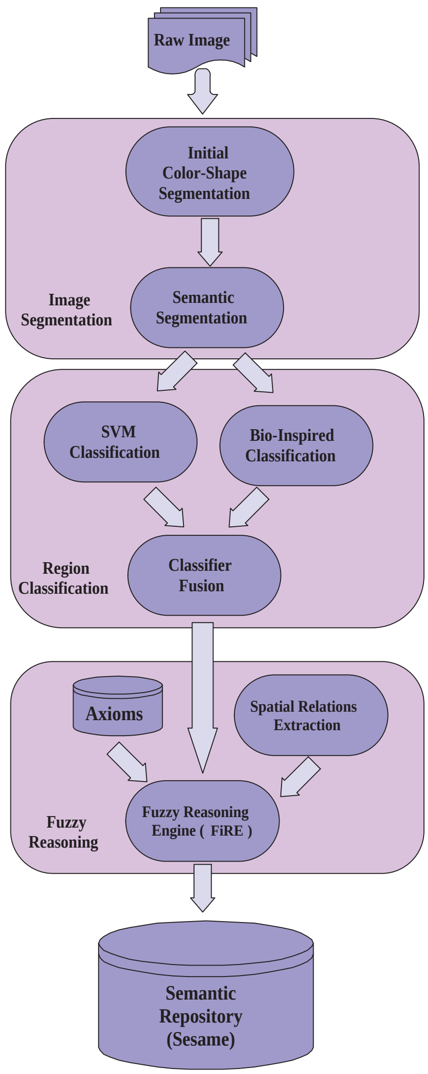

Figure 1: Overview of the proposed architecture

SOM is to represent high-dimensional input patterns with prototype vectors that can be visualized in a usually two-dimensional lattice structure. To further improve the performance of the SOM classifier, the weights of its neurons are optimized following the Particle Swarm Optimization technique [3]. The PSO algorithm is an evolutionary computation technique originally inspired by the social behavior of a flock of birds.

3.3 Classifier Fusion

The analysis results obtained from the aforementioned classifiers are consequently fused, in order to increase the recognition rate for every individual concept. For that purpose, an improved version of an RBF neural network based on evidence theory, called NNET, has been devised [2]. The developed network comprises four neuron layers, namely an input layer, two hidden layers and an output one. Its objective is to associate every image region to one of the predefined set of high-level semantic concepts. A gradient descent technique is followed during the training procedure. Output of the aforementioned network is a single list of concepts with degrees of confidence for all image regions.

4. FUZZY REASONING

In order to further improve the region-based classification, by incorporating the image regions' spatial configuration, and to infer higher-level concepts on a global image basis, a fuzzy reasoning engine is employed, called FiRE[2]. The latter utilizes an ontology capable of handling the imprecise information provided by image segmentation and classification algorithms, which is developed making use of the f-$\mathcal{SHIN}$ language [5]. Using the fuzzy reasoning engine FiRE, which supports f-$\mathcal{SHIN}$ and its reasoning services, extraction of additional implicit concepts that categorize an image and also improvement of region-based classification results can be achieved. The extracted information is stored in a semantic repository permitting fuzzy conjunctive queries for semantic image and region retrieval using FiRE. The repository used for the storage of the fuzzy knowledge base is Sesame[3].

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[2] http://www.image.ece.ntua.gr/∼nsimou/FiRE
[3] http://www.openrdf.org/