Image Classification Using an Ant Colony Optimization Approach

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Abstract. Automatic semantic clustering of image databases is a very challenging research problem. Clustering is the unsupervised classification of patterns (data items or feature vectors) into groups (clusters). Clustering algorithms usually employ a similarity measure in order to partition the database such that data points in the same partition are more similar than points in different partitions. In this paper an Ant Colony Optimization (ACO) and its learning mechanism is integrated with the K-means approach to solve image classification problems. Our simulation results show that the proposed method makes K-Means less dependent on the initial parameters such as randomly chosen initial cluster centers. Selected results from experiments of the proposed method using two different image databases are presented.

Keywords: Ant Colony Optimization (ACO), K-Means, Image Classification and Clustering.

1 Introduction

With the explosive growth of images in digital libraries, there is an increasing need for automatic tools to automatically annotate and organize image databases. Most works in automatic image annotation focused mainly on inferring high-level semantic information from low-level image features. Image recognition techniques facilitate the classification of images into semantically-meaningful categories and then label the images by the keywords that have been manually assigned to the categories. However, one common effort is to implement new techniques to improve inferring semantic information from low-level features in order to narrow the gap between low-level content based image description and their semantic counterparts: The semantic gap.

The fundamental step towards key-word based automatic image annotation is image classification. Automatic image classification is the task of classifying images into semantic categories with or without supervised training. Generally speaking there are two types of classification schemes: *supervised* and *unsupervised*. The task of supervised classification requires relevance feed-back and/or correction from a human annotator. On the contrary, unsupervised classification does not require human intervention. The main task of classification with unsupervised learning, commonly

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known as clustering, is to partition a given data set into groups (clusters) such that the data points in a cluster are more similar to each other than points in different clusters. Thus, the aim is to generate classes which allow us to discover similarities and differences, as well as to provide a concise summarization and visualization of the image content. A large number of classification algorithms have been developed in the past. Each of them has advantages and disadvantages [8]. However, efficient optimization techniques are able to reduce some undesired limitations. The optimization of these algorithms is currently the subject of active studies and promising results have started to emerge.

Recent developments in the optimization techniques are concentrated on natural and biological systems. These systems are inspired by the collaborative behavior of social animals such as birds, fish and ants and their formation of flocks, swarms and colonies. Some recent studies have pointed out that, the self-organization of neurons into brain-like structures, and the self-organization of ants into a swarm are similar in many respects [2]. Ants present a very good natural metaphor for evolutionary computation. With their small size and small number of neurons, they are not capable of dealing with complex tasks individually. The ant colony, on the other hand, can be seen as an "intelligent entity" for its great level of self-organization and the complexity of the tasks it performs. Their colony system inspired many researchers in the field of Computer Science to develop new solutions for optimization and artificial intelligence problems.

In this paper we present an approach to image partitional classification based on the Ant Colony Optimization (ACO) meta-heuristic. We start by briefly reviewing the K-Means algorithm in Section 2. Section 3 describes the characterizing aspects of the used ACO algorithm. In Section 4, the proposed Image Classifier algorithm is presented. Selected experimental results are given in Section 5. Conclusions and future work are discussed in Section 6.

2 The K-Means Algorithm

The K-Means algorithm is one of the most popular squared error based classification algorithm for partitioning N objects into K disjoint subsets S_j containing N_j objects [1]. Given a set of input patterns $X = \{x_1,...,x_i,...,x_N\}$, where $x_i = \{x_{i1},...,x_{if},...,x_{iD}\}^T \in \Re^D$ represents a feature vector and each measure x_{if} is said to be a feature. The aim of K-Means is the minimization of an objective function that is described by the following equation:

$$J = \sum_{i \in S_j}^{N_j} \sum_{j=1}^{K} d(x_i, c_j) \ , \tag{1}$$

where $d(x_i,c_j)$ is a similarity (distance) measure between two objects (feature vectors). c_j is the cluster center of the objects in S_j. Thus, the criterion function J