Ant based Swarm Computing for Image Classification - A Brief Survey

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ABSTRACT

The social insect metaphor for solving problems has become an emerging topic in the recent years. This approach emphasizes on direct or indirect interactions among simple agents. Swarm Intelligence is the collective behavior of decentralized [8], self-organized [4] system whereby the collective behavior of agent interacting locally with the environment causes coherent global pattern to emerge. Classification is a computational procedure that sorts the image into groups according to their similarities [5]. Images can be similar but to measure the similarity pixel-to-pixel comparison is made. Numerous methods for classification have been developed. Exploring new methods to increase classification accuracies have been a key topic. This paper explores the swarm computing methods called Ant Colony Optimization (ACO) to classify imagery.

General Terms

Classification, Swarm Intelligence, Artificial Intelligence, Ant Colony Optimization, Imagery.

Keywords

Ant Colony Optimization (ACO), Artificial Intelligence (AI), Swarm Intelligence (SI).

1. INTRODUCTION

Swarm Intelligence highlights on the problem solving attempt made by the collective behavior of social agent. The problems vary ranging from a Travelling Salesman Problem (TSP) [4] [10] to Classification on the other hand.

With the head way in image capturing device, the image data is being generated in high dimensions. The crucial problem in Image processing is to reveal useful information by grouping the images into meaningful categories. Classification [5] roots out useful information and is one of the emerging topics. Image classification and retrieval utilizes the visual content of an image, to search for similar images in large-scale image, according to user's interest. Various image classification methods [1] have been developed and implemented till date such as the statistical, knowledge-based, neural networks, and other artificial intelligence methods. Nevertheless, these methods still confines as the complexities of images increases. For instance, the most commonly used classification method i.e. maximum-likelihood [5] classifier determines the likelihood between the known and unknown pixels in the sample data. The specification of the sample data is the key to the overall success of classification method. The other method, KBS though easy to understand, is restrained [5] by the long and repetitive process of acquiring information from the expert's experience. Neural network, are best suited for parallel estimation but the rules derived from it are difficult to infer. Artificial Intelligence and its theory provide a scope for image classification. Swarm Intelligence (SI) [9] is a form of artificial intelligence that intends to basically simulate the behavior of swarms or social insects. Swarm refers to any loosely arranged collection of interacting agents that has the ability to act in a coordinated way without any coordinator or external controller. Collective intelligence [11] is the key which basically refers to a shared or group intelligence that emerges from the collaboration and competition of many individuals and appears in consensus decision making in animals, humans and computer networks. A single ant, for example, is not that intelligent but a colony of ants is. As colonies [4], ants react rapidly and effectively to their environment. They find shorter path to the best food source, allocate workers to different tasks, and defend their territory from enemies. Ant colonies make these possible by countless interactions between individual ants. This coordination among the ants does not stem from a 'center of control' [11] rather each ant follows a simple rule of thumb i.e. each ant acts only on local information. A system that exhibits this behavior is said to be self-organizing. And the intelligence the ant's exhibit collectively is called swarm intelligence [9].

2. ANT COLONY OPTIMIZATION

The underlying mechanism for real ant system is illustrated in Figure 1. Ants communicate with each other using pheromones. In species that forage in groups, a forager that finds food marks a trail on the way back to the colony; this trail is followed by other ants (Figure 1(a)), these ants then reinforce the trail when they head back with food to the colony. When the food source is exhausted, no new trails are marked by returning ants and the scent slowly dissipates. This behavior helps ants deal with changes in their environment. For instance, when an established path to a food source is blocked by an obstacle (Figure 1(b)), the foragers leave the path to explore new routes (Figure 1(c)). If an ant is successful, it leaves a new trail marking the shortest route on its return. Successful trails [11]are followed by more ants [4] (Figure 1(d)), reinforcing better routes and gradually finding the best path.

Figure 1(a): Ants moving from nest (source) towards its food (Destination) [4].

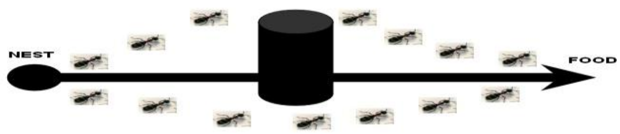

Figure 1(b): An obstacle placed on the way between nest and food [4].

Figure 1(c): Ants randomly choosing the path [4].

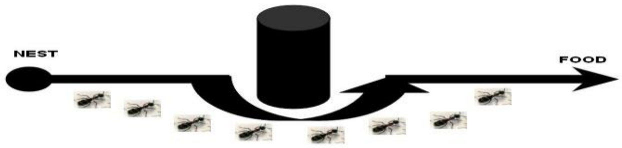

Figure 1(d): Shortest path chosen by maximum ants based on pheromone deposits [4].

The path with the largest amount of pheromone is chosen by ants. Since, pheromone being a volatile chemical evaporates with time; it is obvious that the shorter route will have higher concentration of pheromone [11] [4] [10] compared to the longer routes. The smell of the chemical attracts more ants to join the trial, thus the ants are finally capable to find the shortest route between the nest and the food. This process is described as a loop of positive feedback, in which the probability of ants choosing the path totally depends on the number of ants that have already traversed through the path [3].

3. IMAGE CLASSIFICATION

Image classification is the most important part of digital image analysis. It is always preferable to have an image, showing a magnitude of colors illustrating various features of the underlying terrain, but it is useless unless to know what the colors signify. Two chief classification methods are Supervised and Unsupervised Classification. First method is an image classification approach that is based on the training samples collected by the analyst. The training samples guide to classify the rest of the pixels in an image. The second approach sorts the pixels in the image into clusters without the analyst's intervention and the process is based solely on the distribution of pixel values in a multidimensional attribute space. A class is a group of pixels in an image that represent the same object on the surface of the earth. The classes that results from unsupervised classification are spectral classes based on natural groupings of the image values, the identity of the spectral class will primarily be unknown, must compare classified data to some form of reference data (such as larger scale imagery, maps, or site visits) to determine the identity and informational values of the spectral classes.

The major steps that may be involved in image classification are: Selection of data, selection of a classification system and training samples, data preprocessing, feature extraction and selection, selection of a suitable classification method, post-classification processing, and evaluation of classification performance.

4. ANT BASED METHODS IN THE LITERATURE

Ant colonies provide a means to formulate some powerful nature-inspired heuristics for solving the classification issues. Based on ant's behavior, several classification methods have been proposed in the literature. This section provides a brief description of these methods.

4.1 Xiaoping Liu, Xia Li, Lin Liu, Jinqiang He and Bin Ai in their paper named "An Innovative Method to Classify Remote-Sensing Images Using ACO" [5] extended and modified ACO to rule induction for classifying remote-sensing images (supervised images) and proposed an algorithm termed as ACO-based rule induction [12]. This method considered the mapping from attributes to classes is analogous to the route search by ant colony. An attribute node corresponded to brightness value of the images and is selected once and associated with class nodes.

The method by Xiaoping Liu, Xia Li, Lin Liu, Jinqiang He and Bin Ai highlighted on the detailed procedure to classify remote-sensing images as:

a) Discretization technique [8] to divide the original brightness values into smaller number of intervals.

b) Rule construction using Ant-Miner [12], which employs sequential covering algorithm to discover list of rules (routes) that covers all or most of the training samples in a training set.

c) Pruning the discovered rules (routes) to remove the irrelevant attributes that makes little contribution to the classification.

d) Pheromone updating is done to ensure feedback for the next round of search.

e) Best rule among all the rules constructed by these ants is considered.

There exist numerous unique values for each band in a remote-sensing data even though the brightness values are distinct integers varying from (0–255). Thereby, the above paper focuses on a Discretization technique, named an Entropy method [8], to basically generate intervals by dividing the brightness value of the image.

The Ant-miner program considered various parameters such as number of ants, minimum number of training samples per rule, maximum number of uncovered training samples in the training set and maximum number of iterations. The experiment concluded that from among these four parameters, that the number of ants and the minimum number of training sample per rule are the two most susceptible factors in shaping classification results.

The discovered rules [12] as an outcome of Ant-miner program is further pruned to improve the performance of classification mechanism. The paper defines the rule quality using terminology such as TruePos (true positives), FalsePos (false positives), TrueNeg (true negatives) and FalseNeg (false negatives) as:

$$Q = \left(\frac{TruePos}{TruePos + FalseNeg}\right) \cdot \left(\frac{TrueNeg}{FalsePos + TrueNeg}\right) \quad (1)$$

Where, TruePos: the total number of positive cases correctly predicted by the rule, FalsePos: the total number of positive cases wrongly predicted by the rule, TrueNeg: the total number of negative cases correctly predicted by the rule, and FalseNeg: the total number of negative cases wrongly predicted by the rule. Higher is the value of Q, better will be the quality of rule.

The amount of pheromone of each attribute is updated to ensure feedback for the next round of search by ants and is updated as:

$$\tau_{ij}(t+1) = (1-\rho).\tau_{ij}(t) + \left(\frac{Q}{1+Q}\right).\tau_{ij}(t) \quad (2)$$

Where, ρ is the pheromone evaporation coefficient, τij is the thickness of pheromone and Q is the quality of a classification rule.

Thereby paper "An Innovative Method to Classify Remote-Sensing Images Using ACO" concluded that intelligent methods in comparison to traditional methods prove better for remote-sensing classification especially as the complication of study area increase. This paper has presented method to classify remote-sensing data by using ACO. A technique of discretization has also been proposed for the efficient retrieval of classification rules. Furthermore, an Ant-Miner program has been developed to derive classification rules for remote-sensing images. The derived rule sets are more comprehensible than the mathematical equations used in statistical methods.

4.2 Lintao Wen, Qian Yin, Ping Guo, "Ant Colony Optimization algorithm for feature selection and Classification of multispectral remote sensing image" [3] proposed a new approach by applying Ant Colony Optimization (ACO) algorithm to find a multi-feature vector composed of spectral and texture features in order to get a better result in the classification as it is difficult to obtain better classification accuracy if only image's spectral feature or texture feature alone is considered.

The method by Lintao Wen, Qian Yin and Ping Guo highlighted on the detailed procedure to classify multispectral remote-sensing images as:

a) Feature Extraction.

b) Applying ACO to find a suitable subset features.

c) Use the subset in image classification.

To extract the maximum existing features from the multispectral images reduction methods such as the Euclid Distance Measurement method (EDM), the Discrete Measurement Criteria Function method (DMCF), the Minimum Differentiated Entropy method (MDE), the Probability Distance Criterion method (PDC), and the Principle Component Analysis method (PCA) [12] is used. To further formulate the extracted features to ACO suitable problem, problem is represented in the form of graph wherein nodes denotes the features and edges between the nodes denote the choice of the next feature. The search for the optimal feature subset is then an ant traversal through the graph where a minimum number of nodes are visited that satisfies the traversal stopping criterion.

The heuristic desirability and pheromone factors are combined to form the so-called probabilistic transition rule, denoting the probability of an ant k at feature i choosing to move to feature j at time t:

$$\rho_{ij}^{k}(t) = \frac{[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}}{\sum_{i \in J_i^k} [\tau_{ij}(t)]^{\alpha}.[\eta_{ij}]^{\beta}} \quad (3)$$

Where, τij is the amount of virtual pheromone on edge (i, j), ηij is the heuristic desirability of choosing feature j when at feature i.

Further, unsupervised classification techniques known as finite mixture model analysis (FMMA and an assumption that the feature space as a mixture of Gaussian probability density distribution and the finite mixture model is used to cluster the extracted features.

The paper "Ant Colony Optimization algorithm for feature selection and Classification of multispectral remote sensing image" concluded that the combination of spectral and textual feature obtained by using ACO while classification gives better accuracy and the possibility of choosing features from a high dimension feature space.

4.3 S.N. Omkar, Manoj Kumar M, Dheevatsa Mudigere, Dipti Muley, "Urban Satellite Image Classification using Biologically Inspired Techniques" [7] proposed a method to classify urban satellite images using both supervised and unsupervised classifier i.e. ACO and Particle Swarm Optimization (PSO) as no single classifier can prove to satisfactorily classify all the basic land cover classes of an urban region.

The method by S.N. Omkar, Manoj Kumar M, Dheevatsa Mudigere and Dipti Muley highlighted on the detailed procedure to classify urban satellite images as:

a) Data preparation.

b) Ant Miner Rule Extractor.

c) Multilayer Perceptron Neural Network.

d) Particle Swarm Optimization for Multi-layer Perceptron Neural network.

e) Risk sensitive hinge loss function for misclassified data.

f) Estimation of risk factor mkj.

Initially, while preparing for the data, classification was carried out by dividing the image into different number of classes. An unsupervised classification using the ISODATA algorithm (Iterative Self-Organizing Data Analysis Technique) is carried out using the tool called Erdas Imagine 8.5®. Signature files are created which in turn is used to classify satellite image using Maximum Likelihood Classification (MLC).

An ant-miner, which is an ACO approach to discover the classification rules, is used. Initially, the list maintained to store the discovered rules is empty and the set called training set comprises of all training cases. A rule is added to the list known as rule list when a pre-defined number of training cases are classified and for each training case, rule construction, rule pruning and pheromone updating is performed. The training cases that are covered correctly by this rule are removed from the training set.

The architecture employed for the satellite image classification used is single hidden layer perceptron network. Further, PSO based learning algorithm and the above mentioned single hidden layer architecture is coupled to train the data. Every swarm particle of PSO explores a possible solution and the best position in the course of flight of each swarm is the best solution that is found by the particle.

The neural classifier weights are adapted using the Risk Sensitive Hinge Loss (RSHL) proposed by Suresh et.al. is used to recover the misclassified data in an image during classification. RSHL minimizes both approximation and estimation errors.

4.4 Simranjeet Kaur, Prateek Agarwal, Rajbir Singh Rana," Ant Colony Optimization: A Technique used for Image Processing" [2] proposed ACO for continuous optimization problems on images like image edge detection, image compression, image segmentation, structural damage monitoring.

The method emphasized by Simranjeet Kaur, Prateek Agarwal, and Rajbir Singh Rana highlighted on the detailed procedure using the simple ant-colony system as:

a) Graph Representation of the problem.

b) Initial allocation of ants at each node.

c) Ants possibility Distribution Rule.

d) Update pheromone trial for global updation.

e) Stopping procedure.

Graph representation for the problem using a complete graph rather than a digraph. A continuous problem generally requires the previous value as well as current value to generate the next values. Further, the paper discusses discretization techniques for sampling and dividing the search space for the continuous problem.

The paper" Ant Colony Optimization: A Technique used for Image Processing" concluded that ACO can be used for various applications of image processing which shows continuous behavior. The output varies for the different threshold values and highlights on the importance of pheromone updation.

4.5 Ling Chen, Bolun Chen and Yixin Chen in their paper named "Image Feature Selection Based on Ant Colony Optimization" [1] proposed feature selection using ACO with the objective that is to maintain high accuracy for image classification in representation of original features when a feature set of size n is provided using digraph with 2n arcs to represent the problem. Classifier performance determined by the fitness function and number of selected features is taken as heuristic information to select the optimal feature subset.

The method by Ling Chen, Bolun Chen and Yixin Chen highlighted on the detailed procedure using ACO for image selection as:

a) Digraph with O (n) arcs used to represent a discrete search, where the nodes represent features, and the arcs connecting two adjacent nodes indicating the choice of the next feature.

b) Ants begin its traversal from V0 shown below in figure 3. There are two possible path connecting two vertices and the choice depends on the amount of pheromone (deposited on each node).

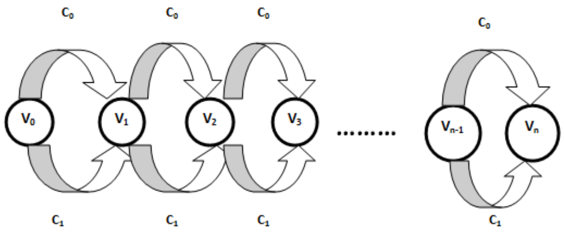

Figure 2: The digraph

c) Ant traverses through the graph in search for the optimal feature subset. The probability of ant at node to choose the arc at time t is given by:

$$\boldsymbol{\rho_i^j(t)} = \frac{[\tau_j^i(t)]^{\alpha} \ (\eta_j^i)^{\beta}}{[(\tau_j^0(t)]^{\alpha} \ (\eta_j^0)^{\beta} + [(\tau_j^1(t)]^{\alpha} \ (\eta_j^1)^{\beta}}$$

(i=1, 2... n; j=0, 1)

(4)

Where, α, β are two parameters that determine the relative importance of the pheromone and the heuristic information.

d) Ant's solution is the selected feature subset, so the quality of the solution in terms of classification accuracy is evaluated using a fitness function f(s) given by:

$$f(S) = \frac{N_{Corr}}{1+\lambda N_{feat}}$$

(5)

Where, NCorr is the number of examples that are correctly classified, Nfeat is the number of features selected in s and λ is the constant to adjust the accuracy.

The paper concluded that ACO for feature selection can obtain better classification accuracy but consider a smaller feature set than other methods.

4.6 Tomas Piatrik, Ebroul Izquierdo, "An application of ant colony optimization to image clustering" [6] proposed the subspace clustering approach that basically assigns weights to the features based on local correlation of data along each directions and the importance of feature selection in clustering. Further this approach is compared with the other existing approaches such as PROCLUS, global feature selection based on K-Means (denoted by GFS-K-Means), and K-Means without feature selection employing the different real world datasets.

The method by Tomas Piatrik and Ebroul Izquierdo highlights the procedure for clustering using Ant Colony Optimization as:

a) Assign both images and feature weights to a cluster where each ant gives its clustering solution.

b) Each ant assigns each image xi, where, 1 ≤ i ≤ n, a probability value Πu, where 1 ≤ u ≤ k.

c) New feature weight is computed for each centroid Cu and for each feature Fl as per intra-cluster similarities.

d) For each image xi, 1 ≤ i ≤ n, generalized centroid are recomputed and pheromone value is assigned to each solution which is further incremented as per the quality of clustering.

e) All ants achieving the same cluster result is considered as the stopping criteria of this procedure adopted in this paper.

The paper,"An application of ant colony optimization to image clustering" concluded that existing methods depends on initialization of centroid what causes unstable clustering. However, ACO technique for the image clustering is comparatively less dependent on the initial parameters which further make it more stable.

5. CONCLUSION AND FURTHER RESEARCH DIRECTIONS

Ant Colony Optimization (ACO) is an appropriate alternative to other methods such as statistical classifier, neural network etc. The algorithm has several features that make it appealing for not just image classification but also for feature selection [1], edge detection [2], image segmentation, image enhancement and many more.

In this paper, survey on ant-based classification has been addressed. Further, the survey thereby is concluded listing several research directions:

a) To adopt a framework of sparse representations to address the problem of feature selection for image classification.

b) To implement the ACO algorithm to classify imagery and compare with the existing algorithms.

c) Transformation of ant classification algorithms into unsupervised algorithms.

d) Hybridization of ant-colony algorithm with alternative clustering methods such as Artificial Bees Colony Optimization (ABCO) [12].

e) Study on other swarm intelligence techniques such as artificial bees based Image classification algorithm.

f) ACO and PSO can be coupled to classify images.

g) Applying ACO to real world applications.

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