

Ant Colony Optimization Towards Image Processing

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Abstract – Ant Colony Optimization (ACO) is an optimization algorithm inspired by ant colonies. In nature, ants of some species initially wander randomly until they find a food source and return to their colony laying down a pheromone trail. Soft Computing refers to the techniques of problem solving which are inspired from the human behavior, natural genetics and the behavior of insects.

Ant colony optimization (ACO) is a technique which can be used for various applications. All these techniques are parallel computational techniques which aim to handle imprecise, incomplete, non-linear and complex data. This paper deals with one of the fields of soft computing- namely Ant Colony Optimization (ACO). ACO is a computational intelligence based approach which is used to solve combinatorial optimization problem. Due to its simplicity and optimal approach it has been applied to routing, scheduling, sub-set, assignment and classification problems. Focus of the current paper is onto the use of Ant Colony Optimization in the field of Image Processing. The details pertaining to each of the approach have been discussed.

This paper proposes an ant colony optimization (ACO) based algorithm for continuous optimization problems on images like image edge detection, image compression, image segmentation, structural damage monitoring etc in image processing. This paper represents that how ACO is applied for various applications in image processing. The algorithm can find the optimal solution for problem.

Keywords: Ant Colony Optimization (ACO), Soft Computing Image Processing.

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1. INTRODUCTION

Ant colony optimization is a technique for optimization that was introduced in the early 1990's. Optimization problems are of high importance both for the industrial world as well as for the scientific world. The development of these algorithms was inspired by the observation of ant colonies. Images are seen to play a crucial role in human beings life. They are our everyday life part laying an impact on all beings. Owing to tremendous advancements in different technology, techniques of image processing have been applied to medical, commercial, military, scientific, and various industrial applications. The image processing field is huge and so looks after an ongoing research in the given area as the quest to focus on specific challenges in the domain. Techniques of soft computing are proven to be a blessing from the processing and analysis of images. The soft computing techniques consist of Genetic Algorithm Fuzzy Logic, Artificial Neural Networks, and Ant Colony Optimization (ACO). The said techniques function in a way that looks after decision

making and also handle uncertainties. Image processing uncertainties comprise of fragmentation noise, incomplete or imprecise information.

ACO is one of the approaches meta-heuristic towards solving the Travelling Sales Man Problem (TSP). Such an algorithm is backed by the behavior of ants as they move to their source of food. Ants are seen depositing pheromones on every path they make a move. Hence, an ant's decision pattern gets moved by pheromones which they leave on every followed path. It helps in communication aided by environment. At first, they pick up a random path from start to a source of food and then find the shortest possible path, one having greater level of pheromone. This in a way account's for the ant colony to track the path from the source to the destination in the least possible time.

ACO main features include:

- An approach of multi agent that is based on colony: Approaches based on ACO along with its optimization process is performed by the ant's collective system. Every ant adds to the solution yet to solution convergence turns possible by the ant's collective behavior.
- Distributed and Concurrent System: Here, ants work parallelly to attain a solution for the problem. Such an approach helps solve problems of NP hard. Further, the ants exchange information amidst them to find an effective solution.
- Iterative system: For every ACO iteration, they are designed to better the solution and so with each for the iteration passing, the solution only gets better. The used reinforcement post each ACO iteration helps attain this objective.
- Search Capabilities: ACO is seen to explore the total search space so as to attain the capabilities of global search. Further, the pheromones get updated by the ant present on every arc when forming a partial solution. Hence, application of a local search in ACO helps enhance the solution. The local search step is optional yet suggested in, better the algorithm's entire performance.

To solve the TSP problem, three ACO variations have been proposed: ant density, ant cycle and ant quantity algorithm. The prime difference in ant density, ant quantity, and ant cycle algorithms is the undertaken approach for updating the levels of pheromone. For the algorithm of ant density and ant quantity, pheromones get updated post each move, however in the algorithm of ant cycle algorithm, the updates take place when the ants construct tour. The ACO algorithm general process has been depicted in the given below flowchart.

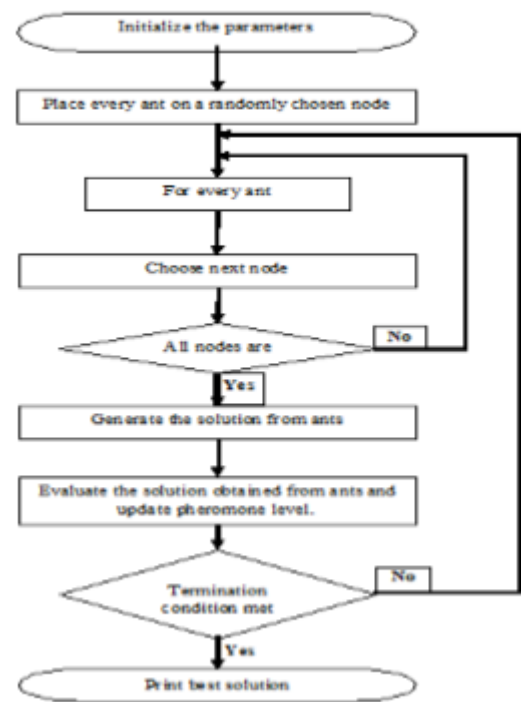


Figure 1: Ant Colony Optimization Flow chart

Any of the optimization problem can be solved taking help of ACO in case we represent the problem using a graph in the search space being discrete having transitions represented in a manner that is valid. Few other factors that are important:

- The phenomenon for updating pheromones so as to accommodate a positive feedback,
- Mechanism to construct and represent solutions,
- Constraints as defined across the problem as the construct of method has feasible solutions,
- The function of evaluation as it serves being the generated solutions measure, and
- Condition of termination.

2. EDGE DETECTION

Edges presented in an image have been attributed to the highly sharp transition starting from higher intensity to extremely lower intensity regions which further provides relevant information on the object. Range of methods to detect the objects edges are present in the literature like difference method, statistical methods, and methods based on curve fitting.

Classical methods are based on calculation of the derivative of first directional so as to find the edges

location. The edge detectors of zero-crossing along with the second derivatives have been incorporated with the operator of Laplacian to provide better accuracy as compared to the operator of first derivative. The Canny edge detector has been based on Gaussian detectors concepts and the commonly used edge detectors. This gives improved performance which is but computationally expensive as compared to classical methods. All the said methods are seen to extract edges by undertaking the specific formulas which promotes smoothing functions. However, the prime drawback in all edge detection conventional approaches is that these approaches are computationally expensive. And the major reason being that such operation should be executed in image pixels and so the time of computation is image proportional.

The ACO based approaches is seen to own the potential to overcome said limitations using the method of parallel implementations that turns them evitable for the distributed systems also. The techniques of edge detection that is relies on ACO utilizes ants move. Such a movement accounts to the formation of pheromone matrix. Information of Edge on each pixel is then represented by a pheromone matrix entry. Variation in value of intensity in the image is prime for ant's movement.

In an approach based simply on ACO, they are seen to be successful in image's edge extraction. Primarily, few numbers of ants are randomly distributed across the image. Such ants then update their intensity of pheromone on each iteration. Then the approach would use simple rules set for updating the intensity of pheromone. A model of image vision is designed in so as to effectively extract the image edges. Variation in ACO is used for deriving a relationship in image size and the algorithm parameters. Few ACO extensions are seen to raise post development. Another technique used to detect edge as given in seen to rely on the ant colony systems distinguishing features. Here, establishment of pheromone matrix is done by ants movement along with pseudorandom proportional rules used to update the matrix. But adjustment of several algorithm parameters is based on the image's nature. Adjusting ACO parameters lays a major problem with hybrid approaches as emerged to put up on these parameters. ACOs combined approach with pixel intensities statistical estimation in the circular neighbourhood for updating the intensity of pheromone to aid edge detection in images is given. ACO along with Fuzzy derivatives to detect edges are used in. These derivatives of fuzzy calculate its probability that alternatively decides total ants present in the algorithm.

Proposal for the model is proposed which utilizes filters of three linear spatial: high pass, low-pass and the edge enhancement filters. The edges strength at each pixel has been generated via spatial convolution. The values of edge strength are given

as the fuzzy system input. The decision if any pixel is the edge or not relies on fuzzy rules. The method of Mamdani defuzzifier is used for edge detection.

Selection of ACO parameters has proven as a challenge in all suggested approach. Such an ACO complex problem in edge detection can be solved with the help of the algorithm of particle swarm optimization for optimizing the said parameters.

3. EDGE LINKING

Techniques of Edge detection suffer from few drawbacks comprising of missing true edge, false edge detection, producing thick or thin lines along with the problems arising be sure of noise.

Connecting the edges broken accurately is not a task. The original image local information has been used generally to connect the broken edges. A technique simple is linking the broken edges for improvement of the technique of edge detection. This is seen to work based on the idea that edges end points are core components that have relevant information and so one can draw direct lines between the two broken edges.

Acquisition of a mask is done to find the end points direction and then estimate the line linking cost that further determines if the line has been selected. The methods advantage is mainly the simplicity and the implementation ease. However, on contrary, it also leads to generation of edges incomplete. In a different classical approach, the Hough transform has been applied on image edge with extraction of specific shape for connecting the broken edges. An edges different shape turns the method unfavorable.

In the method based on ACO is used for linking the edges that are broken. It is based on the fact that every image pixel gets connected to 8-neighborhood pixels. Adjacent pixels distance has been estimated using original image. The detection method of conventional edge has been used to detect edge where ants have been placed on the end points extracted. The image has hundreds of endpoints which feeds plenty of complexity in the process of search. This further account's to redundancy since different ants search in a same region. In order to cope with the issue, ants are labeled and separated into groups. Such ants groups seek to repair the edge breaks. Given the search course, the range has been extended for compensable edge determination.

In the approach that is ACO based, proposal is given to find the noisy image edges. Contamination of the images done through the noise of Gaussian and salt and pepper. The technique proposed can detect edges with the help of ACO considering the frequency of edge is close

to noise frequency. Then the approach as ACO integrated and edge detection are proposed to provide clear and continuous object boundaries. This approach is capable of suppressing noisy surroundings. Hence with ACO, edge linking major issues gets resolved.

4. FEATURE SELECTION (FS)

Selecting an appropriate feature is a problem that has been encountered in several engineering field along with image processing. Image recognition, pattern recognition, along with text recognition acts as image processing subfields that use the selection of feature as processing part. All standard method of feature extraction has been used to extract the images features. This features could either be global or local i.e. features are of images specific object or maybe complete image. All these features comprise of objects size, texture variations, colour variations, spatial correlation, contrast, cluster prominence etc. The image representation is done with a feature vector, that is capable of capturing the properties, and the task that leads to images key classification. Such process lowers the features dimensionality in a way reducing the processes overall complexity and data analysis. In layman's term, the prime goal in image processing feature selection is removal of redundant, useless, and spurious features that further reduces the complexity of computation.

Exhaustive search gives the problem an optimal solution yet comprise of the evaluation of all feature sub set and further ads to the exponential complexity turning it inappropriate for applications. In consideration to certain datasets, the above exhaustive search is seen to use subset of tens of billions to determine feature optimal to turn it impossible.

Hence, the feature selection is more of a NP hard problem. The capability of ACO is evident in problem solving that is NP hard. So, ACO follows the method of global search and then determines the subset of optimal solution from the total feature space based on ant's behavior. The problem of FS is graphically represented and here all features get reflected by the graph nodes so the ants recognize the apt features from the graph.

Methods of feature sections are broadly classified into two types: Wrapped Methods and Filter Methods. The core difference between the said methods is in the criteria of evaluation. Filter Methods chose the subset of best feature based on data's statistical properties whereas the wrapper methods are seen to use the learning algorithm for guiding the subset of feature selection.

In the methods of filter, the selection of feature subset has been performed as the step pre-processing using independent components analysis, PCA, class separability, mutual information

computation, variable ranking etc. Hence, with the said feature approach, subsets are chosen on the basis of statistical properties. This fails to consider the feature selected however in case of Wrapper method, this uses learning algorithm to evaluate the selected subset feature effect.

Both the approaches diagrammatic view is shown in below given Figure as adopted from concepts.

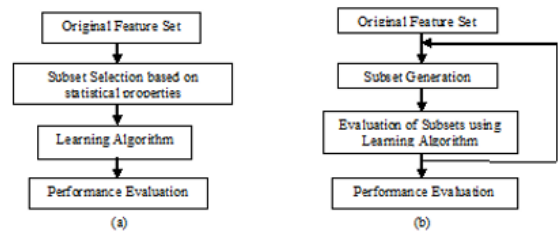


Figure 2: (a) Filter approach; (b) Wrapper approach

5. SEGMENTATION

The Image segmentation has been defined as the partitioning process of a digital image into varied segments. The above said smaller segments appear to be meaningful and so is analysed easily, thereby simplifying the complete image processing. Here, in the given process, each pixel gets labeled and ones having same features are tagged with a similar label. The segmentation task appears to be easy but few factors like image contrast, illumination variation, image complex nature, image noise, and diversity deem it challenging. Several approaches such as clustering, thresholding, and histogram based, compression based, region growing, edge detection, watershed transformation and the segmentation based on model are proposed to segment image in literature.

Clustering is one of the highly recommended segmentation methods and has been put up in several situations. However, it has a huge optimization problem with reasons being optimization's large search space and the nature of objective function being non-convex. This might lead to a huge amount of local minima. In the said approach, the image is seen as the data set multi-dimensional that is classified into several parts based on a specific predefined criterion. Clustering techniques improvements are obtained by fuzzy theory integration, ACO based evolutionary techniques and neural networks. Plentitude of approaches are proposed in literature so as to enhance the accuracy and lower the time.

The ant colony's approach on the basis of multi-agent is put up by several authors where the ant system of Max-Min is used for image segmentation by cluster formation. Images each pixel is them mapped to the closest cluster. This approach performance is further enhanced by integration of

AGO characteristic meta-heuristic and Markov Random Field (MRF) for image segmentation. Simple agent populations are used in an algorithm for constructing the candidate partition by the labelling of relaxation along with contextual constraints. The major issues linked with the algorithm based on ACO are randomness of search process and used huge convergence computations due to the coefficient evaporating constantly. The Author in 50 has the idea to set the primary cluster center for problem dealing. The algorithm proposed has a small window to lower the total computations. Coefficient constant evaporation accounts for stagnation or early convergence that is further prevented by enabling the coefficients to alter with the ant's number. Another segmentation based on ACO is given by Xiao et al that has been inspired from the decision algorithm of multistage. Precise contours are obtained by finding the constrained region's optimal path. But these algorithms have lower rate of convergence due to the random selection of Center of clustering. To cope with the said issue, another algorithm has been proposed by the author namely the k-means ACO clustering based algorithm, k-means clustering is applied to find the centres of accurate clustering. Even if k-means clustering is seen to be useful yet the drawback is dependent on the initial state. The above issue gets resolved and a hybrid algorithm as presented by the authors help solves the problem of clustering of nonlinear partitioned. A fuzzy hybrid of adaptive PSO, optimization of ant colony and algorithm of k-means are proposed and can effectively identify the partition of better cluster as compared to existing approaches.

A significant improvement as suggested in. An approach being reliant on the idea to extract several features like pixel neighborhood, gray value, and gradient for improving the search and clustering process. Algorithm is seen to rely on the clustering center initialization and enhance the approach of heuristic ACO for acceleration of the search process.

Traditional approach based on ACO is seen to suffer from hard path and probabilistic choosing problem. Author has used a fuzzy and soft scheme in addition to the ACO for dealing with the given problem. The image pixel is thought to be an ant. Information both heuristic and pheromone on each center of cluster has been used for calculating the fuzzy set membership function. Further, performance gets improved using the spatial information.

It is analysed that center of cluster are randomly selected so the trapping probability is high in local minima. For resolving the issues, authors gave a hybrid scheme that is based on the method of Differential Evolution and Algorithms-artificial Bee Colony (ABC). Firstly, the center of initial clustering are obtained with the seeds taken from algorithm of cluster center followed by the application of evolutionary algorithm to determine a solution

globally. Author here have given an algorithm of hybrid clustering that integrates clustering of ACO based into probabilistic clustering of C-means for segmentation of noisy image segmentation. The above algorithm can solve the problems of coincident clustering by using the pixel information pre-classified.

6. IMAGE COMPRESSION

The core aim of compression of an image is removal of the redundancies so as to utilize efficiently the storage space and transmission bandwidth. Any raw image would have Mbs of data that can be further lowered by the techniques of image compression. There exist two kinds of image compression - lossless compression and lossy compression. In the lossless techniques, user's information is not lost and so the image original is reconstructed exactly yet the ratio of compression is low. In case of the techniques of lossy compression, there do occur information loss hence if the image is further decompressed, this would not be same as the original one yet similar. The ratio of compression is high and also the quality of image degrades. Several techniques of lossy compression are available such as vector quantization, transformation coding, block truncation coding, and fractal coding. It is seen that with higher ratio of compression, there are more techniques of fractal coding. The technique of Fractal coding works by division of the initial image to a small, squared, non-overlapping blocks, called the parent blocks. Every parent block is then divided into a minimum of 4 child blocks or sub blocks and each block is then compared to a subset of parent's size blocks that are possibly overlapping. Determination of Larger block done by finding the least possible difference of it with the child block. Calculation of grayscale transform is done to map the level of intensity between child block and large block precisely. Such Fractal Image Compression is seen to rely on several block similarities within an image. The techniques of linear regression are embedded in the procedure of encoding for finding the apt solution for several blocks. Such a technique has been emerged as a popular method of coding in the current years. But the complexity of computation detains the applications. Further this technique of compression shows poor quality of image as applied to corrupted images. Then this account for a new idea of the robust compression of fractal image.

For reducing the ant colony algorithm's encoding time, they have proposed in. The produced fractal encoding by the algorithm of ACO are completely identical to the one same as the full search. The prime advantage here is the time reduction. So the algorithm is realized as the coding fractal image well.

Author further compare the evolutionary approach performance such as PSO, GA, and ACO for the compression of fractal image which show the ACO performance to be better than other techniques.

7. CONCLUSION

ACO is seen to have tremendous potential when solving several tasks of image processing like edge linking, edge detection, segmentation, feature extraction, and also image compression. Several ACO algorithms details to solve the said issues are discussed. Methods conventional are used to solve problems and presented when highlighting the ACO advantages over given techniques. The given paper shows ACO in-depth analysis over the task of image processing thereby laying researches future directions. Several other techniques such as Cuckoo Search⁶⁵ are used for purpose of optimization. Future research should lay focus on the ACO comparison with latest methods. And the search engine optimization in in66 to be assessed using ACO.

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