Multiple Ant Colony Approach to Edge Detection

6.1 Introduction

The image processing domain and particularly the image segmentation aims to extract information from a picture. At a first level and without considering frequential spaces or wavelets spaces, we can specialize this extraction as being the detection of two primitives [25]

(1) the edge (or contour) detection and

(2) the region detection.

A third category consists in detecting both regions and edges at the
same time. A recurrent problem for the image segmentation exists, a same kind of primitive can be represented on an image through pixels with different manners. Thus, primitives are difficult to detect using a single operator, or an operator which has the same settings when it is applied on the entire image.

Primitives representation mainly depends on the image resolution such as thickness of edges, size of regions, and image/acquisition quality like clear or blurred edges, noised regions. Operators in image processing algorithms applied locally around a pixel $P$. According to its settings, an operator affects more or less pixels surrounding $P$, which defines the location where this operator is applied. To solve this problem of representation variability, we need to locally adopt interpretations on the image, and not globally through only one algorithm applied on the entire image. In the scope of this thesis, we focus on this issue by using a Multiple Ant System - MAS approach, and we only consider the edge detection.

Usually, an edge is characterized by an abrupt gray level change between two regions. However, edges may be blurred, the gray level change is not abrupt but spread out through a lot of pixels. As for region detection, edge detection depends on how the used algorithm is tuned. Some settings detect straight visible edges, while others detect partial edges.

So, the difficulty is to define algorithms which are able to detect both partial and correct edges, without being disturbed by noise. Another difficulty is to manage hidden edges in order to then detect closed edges. Multiple Ant Colony approach is an interesting solution since they allow the cohabitation of several
algorithms. For example, agents can analyze problems they are locally confronted with, and then use the algorithm which seems the more suited to their local context. Within the image processing domain, how Multiple Ant Colony approaches are used in extracting feature in the images are explained and tested in this chapter.

This chapter is organized as follows. In Section 6.2, we study about the multiple Ant Colony approach, and in Section 6.3 the contributions that already use Multiple Ant System for image processing are explained. In Section 6.4, we give an overview of our edge detection approach. In Section 6.5, we present about the colony level interaction. Section 6.6 deals about the proposed technique and the algorithm used to detect edges. We end up by discussing our results in section 6.7.

6.2. Multiple Ant Colonies Optimization Approach

Multiple Ant Colonies Optimization (MACO) is an extension of the Ant Colony Optimization - ACO framework where a number of ant colonies working together to solve some combinatorial optimization problem. Gambardella et al. [10] proposed multiple ant colonies system for the vehicle routing problem with time windows. The algorithm has been designed to solve vehicle routing problems with two objective functions which are the minimization of the number of tours or vehicles and the minimization of the total travel time, where number of tours minimization takes precedence over travel time minimization. The basic idea is to coordinate the activity of different ant colonies, each of them optimizing a different objective. The results of this approach have shown to be competitive with the existing methods. A similar approach has been used by Jong and Wiering
to tackle bus-stop allocation problem with n bus stops and m bus-lines. A solution is to construct m bus lines, each one consisting of a sequence of n bus-stops that minimizes the average travel time. The results of the new algorithm outperformed the results obtained from greedy algorithm and simulated annealing.

A Multiple Ant Colony Optimization - MACO algorithm based on colony level interaction has been proposed by Kawamura et al. [12]. This algorithm used large number of parameters that must be set in advance. These parameters determine the effect of each colony to all other colonies and they organized as an array of size M×M, where M is the number of colonies. No specific way of choosing this large number of parameters was shown. The effect of a colony towards another colony may be positive or negative.

Different colony structures were tested with some parameter setting. The algorithm tested on some Travelling Salesman Problem - TSP instances and the results were better than Ant System results but did not compare with the best performing ACO algorithms like ant colony system.

We used the same approaches for our work to identify the edge of an image, and the resultant image contains less noise and few false edge.

### 6.3 Related work in Image Processing

Several works associating Multiple Ant System and image processing already exist [13, 21, 24, 28]. Different Multiple Ant System properties and mechanisms have been used in these approaches such as cooperation, negotiation, adaptation, emergence, etc... Co-operative approaches enable agents,
each associated with an image processing algorithm, to share different collected information. More precisely, a quadtree algorithm is used to identify primitive regions, and a Shen filter is used to determine edges. The solution consists in merging regions according to their homogeneity. An edge agent can prohibit the fusion between two regions if it is located in between. Cooperation enables the cohabitation of several image processing algorithms. It increases the quality of the segmentation by confronting the information provided by the different algorithms.

In the proposed approach, each ant colony is associated with their own settings of image processing algorithm. Each Colony knows which operators it needs to apply, and what is the expected result of its application on the environment. At the beginning, acquaintances evolve randomly, but as the cooperation process progresses, each ant knows the utility it can have to help its neighbors to accomplish their goal.

Yanai [13] developed a Multiple Ant System where the agents are used to structure the perceptions of the system. The proposed Multiple Agent System recognizes objects on a real 3D scene. The system extracts primitive information like lines (Hough transform), edges (Snakes) or regions using different types of algorithms. Each agent is located on the image and builds a set of coherent primitives called representation. This representation is compared with a database to identify a potential object in the scene. Then, the agents interact to negotiate their local representations.
Communications between agents make their representations evolve, in order to find common coherent representations. The system reaches its goal (objects recognition) when all the agents agree on their representations. Mazouzi et al. [28] uses an adaptive Multiple Agent System that enables the emergence of edges detection on pictures representing 3D scenes. The solution consists in defining the segmentation process using the already existing segmentation.

To conclude, multi-agent system can be used through several ways. We have seen in [28], that Multiple Agent System are used to enable the cohabitation of several image processing methods. These approaches give good results, but the benefit that comes from the use of the Multiple Ant Approach paradigm is limited by the used algorithms that only provide results at the macro level. However, there exists several approaches, only there is certain work that deals with the medical image processing problems as we explained them on Chapter 5. Hence our thesis focused on a Multiple Ant approach which is adopted to the edge detection problem.

6.4 Overview of our approach

Several ant algorithms are presented in the literature among them Ant Colony System (ACS) and Max-Min Ant System (MMAS) are the best performing algorithms [7, 15]. The performance of these algorithms is interesting. Nevertheless, these algorithms are still far from being perfect, these algorithms can get a good solution at the early stages of the search process but unfortunately all ants quickly converged to a single solution and then the algorithm is unable to improve that
solution. This is a common problem that all ACO algorithms suffer from regardless of the application domain; it is called search stagnation problem. The chance of stagnation proportionally increases with the increase of the problem size.

One new direction of ACO researches that focus on enhancing the performance of ACO and reducing the effect of the search stagnation is the use of Multiple Ant Colonies Optimization (MACO) where several ant colonies work together to collectively solve an optimization problem. MACO offers good opportunity to explore a large area of the search space and find optimal solution. MACO seems to be appropriate approach to improve the performance of ACO algorithms [7],[15]. Interacted Multiple Ant Colony follows this approach and tries to improve the performance of ACO algorithms by utilizing several ant colonies with certain techniques to organize the work of these colonies.

The application domain that initially motivated this work is the feature extraction on ordinary and medical images using Ant Colony. In the scope of this paper, our approach is focused on 2D images. As a first approach, we developed a system that is able to build a representation of the edges which are present on an image. These detected edges are represented as grayscale values. High grayscale values on a located pixel means that there is a high probability that this pixel represents an edge. However, if noise can be present on the source image, and then that it can be created false edge representation on the destination image and some edges will not be detected by image processing algorithm. Our work goal aims to construct a Multiple Ant System model which overcomes some of the above
said problems. The Multiple Ant System model developed in this thesis aims to identify an image’s edge using swarm intelligence. First, the system initializes a predefined number of ant colonies. They have a more precise perception of edges through ACO approach which enables them to have a precise edge detection in an image.

6.5. Colony Level Interaction

Interacted Multiple Ant Colony Optimization framework is recently proposed in previous work of the authors [1],[2]. In this framework there are two levels of interaction the first one is the colony level and the second one is the population level.

The colony level interaction can be achieved through the pheromone depositing process within the same colony. The pheromone updating mechanism is responsible for the implementation of this kind of interaction. The population level interaction is achieved by evaluating the pheromones of different colonies using some evaluation function. The responsibility here is of the pheromone evaluating mechanism.

In our work we implemented colony level interaction based on ACS. Each colony has its own pheromone that is used as an interaction between the ants of the same colony. The interaction between ant colonies using pheromone can be organized in different terms.
6.6 The proposed Techniques

This section contains the detailed view of the proposed technique.

6.6.1. Pheromone evaluation technique

The proposed technique evaluating the pheromone as an average of the pheromone values of all colonies on some edge. Each ant makes a probabilistic decision when it needs to move to a new pixel. The probabilistic decision is based on heuristic information and pheromone information. Pheromone represents information about previous experiences of the ant’s own colony.

The proposed mechanism is a composition between the pheromone of ant’s own colony and the average of the pheromone of other colony. The ants of the first colony choose the direction from North to South where as the second colony choose the direction South to North. Totally K ants are randomly assigned on an image. The image is represented by an N X N array with values between 0 and 256 according to the 8 bit gray level of the pixels. The ant moves from location i to j according to a transition probability [3]. A decision about each pixel is made to determine whether to include in edge or not by applying a threshold T.

Local pheromone updating includes that each ant updates the amount of pheromone on pixels it uses in order to give a more chance to other pixels to be chosen by the future generations. Local pheromone update is applied by each ant on the visited edges. The different pheromone evaluation values for the same edge in the same iteration is given in equation 6.1
Where

$$P_{ij}^{v} = (1 - \gamma) P_{ij}^{v-1} + \gamma P_{q}$$  \hspace{1cm} (6.1)$$

is the pheromone of colony $v$ on the edge from pixel $i$ to $j$.

$P_{q}$ is the initial pheromone value

$\gamma$ is another pheromone evaporation parameter with a value in the range [0,1].

Given that for each edge there exists pheromone values each belongs to a single colony. Average pheromone evaluation function evaluates the pheromone on any edge as an average of the available values. The average pheromone evaluation function $f(P_{ij})$ on the edge $(i,j)$ is defined as in equation 6.2

$$f(P_{ij}) = \frac{\prod_{k=1}^{m} P_{i_j}^{h,k}}{M}$$  \hspace{1cm} (6.2)$$

To test the effect of the proposed technique, several experiments ran with two colonies using different values for the pheromone evaluation rate $\lambda=0.8$, and $\lambda=1$. The other parameters and the procedure are used as in [3],[4]. The results were better than those obtained using only one Colony [3],[4]. Figure 6.2 shows the result of using this proposed Algorithm [3],[4] with only two colonies. The results improved using this technique, however, the best result can be obtained when Multiple Ant Colonies with parallel run is implemented which is a future work.

6.6.2. Proposed Algorithm

The algorithm of [3],[4] with some modification is used in this chapter to identify the edges. In this algorithm, let $M$ and $m$ be the number of colonies and the number of ants in each colony. The k-th ant in the h-th colony is denoted as $(h,k)$
ant. If $M=1$, this algorithm behaves like a original algorithm without colony level interactions.

**Algorithm ACOMul**

**Input:**

i) Medical Image and the Gray value of each pixel in an image stored as a matrix

ii) Initial value of the parameters like $\alpha, \lambda$ etc and Initial pheromone value

iii) Number of Ants in each colony $m$ and the Number of colonies $M$

iv) Threshold value

**Output:**

i) Pixels that are selected by Ant of $M$ Colonies

ii) Computed Average

iii) Edge image formed by the multiple colony

**Begin**

*Initialize all the parameters*

For all the Colonies $h = 1$ to $M$ do

For every edge of pixel $(i, j)$

Set $\tau_{i,j} = Initial$ value

Repeat until all the pixels

For each colony $h = 1$ to $M$

For each ant $k = 1$ to $m$

Repeat
Get the pixel \( j \) to move

Move the \((h,k)\) ant to next pixel \( i \)

Compute the changes in the pheromone

Update Pheromone in \( h \) colony

Until all \( h \)

Compute the Average for each colony

Connect all the edge points to form the edge map

Perform Thresholding

End
6.6.3. Experimental Results

Fig 6.1. The histogram, (a) Heart, (b) Brain, (c) Hand

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Fig 6.2 Edges using two colony for Heart and Brain

(a), (d) - $\lambda=0.8$, Pheromone = 1000

(b), (e) - $\lambda=1.0$, Pheromone = 2000

(c), (f) - Final image edge
(a), (d) - \( \lambda = 0.8 \), Pheromone = 1000

(b), (e) - \( \lambda = 1.0 \), Pheromone = 2000

(c), (f) - Final image edge

Fig 6.3 Edges using two colony for Hand and Lart
(a), (d) - $\lambda=0.8$, Pheromone = 1000

(b), (e) - $\lambda=1.0$, Pheromone = 2000

(c), (f) - Final image edge

Fig 6.4 Edges using two colony for Tower and Vase
6.7 Conclusion

The experimental results show that using multiple ant colonies to explore the edge offers the opportunity to find new and better edges, and also it reduces the chance of noise.