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Edge detection improvement by ant colony optimization

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Abstract

Edge detection is a technique for marking sharp intensity changes, and is important in further analyzing image content. However, traditional edge detection approaches always result in broken pieces, possibly the loss of some important edges. This study presents an ant colony optimization based mechanism to compensate broken edges. The proposed procedure adopts four moving policies to reduce the computation load. Remainders of pheromone as compensable edges are then acquired after finite iterations. Experimental results indicate that the proposed edge detection improvement approach is efficient on compensating broken edges and more efficient than the traditional ACO approach in computation reduction.

Keywords: Edge detection; Ant colony optimization (ACO); Pheromone trail

1. Introduction

Edges often carry important information about an object, when shown as large gradient magnitude. Edge detection strategies seek out obvious edges in an image. Traditional edge detection approaches, like Sobel or Canny operators (Canny, 1986; Gonzales and Woods, 2002; Sharifi et al., 2002), commonly extract edges by adopting specific templates, or in combination with smoothing functions. However, traditional edge filtering methods often result in some drawbacks like broken edges. Therefore, many methods have been proposed to link these broken edges in order to improve edge detection (Ghita and Whelan, 2002; Hajjar and Chen, 1999). Endpoints of edges preserve important information, and some methods try to draw reasonable direct lines between pairs of broken edges. Ghita and Whelan (2002) adopted a mask to acquire the direction of endpoints in order to estimate the cost of the linking line. The cost and direction of each directed line determines whether the line is selected. These methods are in general simple but their main inconvenience is the fact that they return incomplete edge structures.

Some edge linking approaches perform Hough transformation (Parker, 1997; Gonzales and Woods, 2002) on edge image, then extract the specific shape to connect broken edges. However, the edges do not always have fixed shapes. Some other methods (Ng et al., 1999; Sharifi et al., 2002) adopt hybrid techniques to connect broken edges. Insufficient information always leads to inappropriate results. Thus, broken edges are hard to connect accurately. Edge linking should consider at least two endpoints in order to generate linking edges. Therefore, possible compensable edges need to be sought from these endpoints. The local information of the original image can be further analyzed to help link broken pieces and search lost edges. This searching procedure is a globally tree-like topology.

Ant colony optimization (ACO) is a heuristic method that imitates the behavior of real ants to solve discrete optimization problems (Dorigo and Stűtzle, 2004). The created artificial ants behave like intelligent agents with memory and ability to see. These ants share their experiences in order to search optimal paths iteration by iteration. Since

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the starting states of ants and the terminating rules are defined, ants adopt state transition rules to construct their optimal solutions.

ACO is efficient in solving tree-like problems. Furthermore, the constructive steps of each ant can be different in the same iteration. It means that no requirements are demanded to estimate the total number of probable optimal solutions. This condition differs from other evolutionary computation methods like genetic algorithms. Some researchers have adopted ACO to solve specific image processing or machine vision problems, like imitation and reproduction of human vision perception and optical illusions (Vallone and Mërigot, 2003), texture classification (Zhuang and Mastorakis, 2005; Zheng et al., 2003), and edge detection (Zhuang and Mastorakis, 2005).

In solving edge detection problem, each pixel of one image is assumed to be connected with its 8-neighborhood pixels. The distance between adjacent pixels is estimated from the original image, and the ants are placed on endpoints extracted from traditional edge detection approaches. These located ants attempt to repair breaks of edges, and extend their searching range to find compensable edges.

The rest of this study is organized as follows. Section 2 introduces the concept of ant colony optimization. Section 3 explains how to improve edge detection by ant colony optimization. Section 4 presents some experimental results and brief conclusions are given in Section 5.

2. Ant colony optimization

Ant colony optimization (ACO) is a multi-agent system (Dorigo and Stűtzle, 2004) that iteratively searches for optimal solutions. Elements of optimal solutions are extracted according to the shortest path of ant tours. Ants deposit their searching reward, pheromone, on their passed paths. These feedbacks may attract other ants to follow partially with a probability called state transition rules. This probability consists of two weighted factors, namely trail intensity and route length. State transition rules imply that shorter and more ant-experienced paths attract more ants to pass through. However, as with real ants, not all ants follow the most attractive paths, instead a few ants try to explore new paths. The process of taking the maximal probability path is called exploitation, and the process of selecting the next path by probability is called exploration.

ACO can be applied to other optimization problems by modifying evolutionary procedures. However, the following elements need to be clearly defined:

1. A problem graph that includes paths, cost of moving, and the number of ants.
2. Initial states and moving rules of ants.
3. Termination conditions of ants.
4. Definitions of pheromone reward and natural evaporation.

The ACO mechanism has the following desirable properties (Dorigo et al., 1996):

1. ACO is versatile in that it can be applied to similar versions of the same problem. An example of a similar version might be the traveling salesman problem, which can be directly extended to the asymmetric traveling salesman problem.
2. ACO is robust, and can be applied with only minimal changes to other combinational optimization problems, such as the quadratic assignment problem and the job-shop scheduling problem.
3. ACO is a population-based approach, and allows positive feedback exploitation to be adopted as a search mechanism.

3. Edge detection improvement by ant colony optimization

3.1. Redundant search reduction

The proposed approach relies on ants searching paths among break edges and exploring compensable edges. Ants

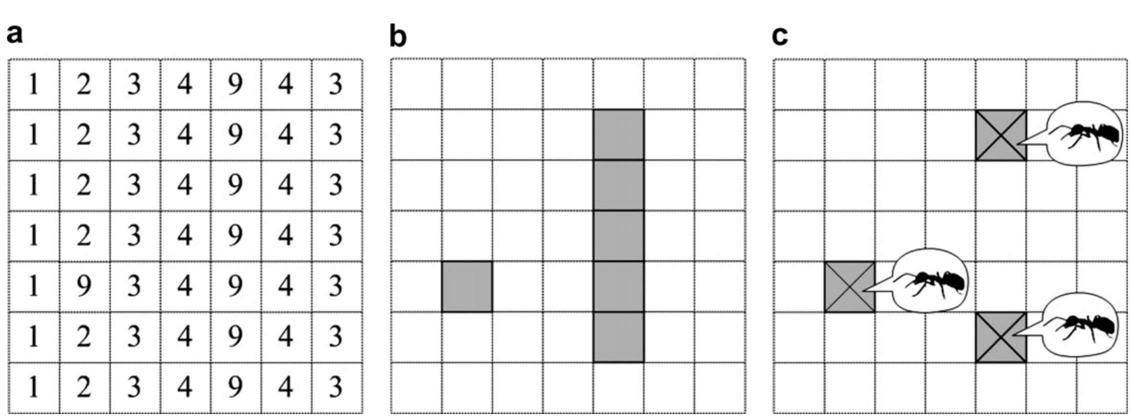

Fig. 1. (a) Original image. (b) Traditional edge detection of (a). (c) Placing ants on all endpoints.