Behavioral Decision Based on Abstraction of Pheromone Distribution for Transport Vehicles

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Abstract

In this paper, we focus on behavioral decisions for empty transport vehicles e.g., they should wait on their place or go to other places. Effective behaviors of empty vehicles enable to decrease waiting times of customers. Our algorithm to acquire such effective behaviors is based on transport experiences of vehicles (i.e., history). It means that vehicles adjust to their city environment by learning trends of transport demands (e.g., amounts and directions). Our algorithm consists of **learning** *and* **abstraction** *stages. In the learning stage, vehicles acquire low-level rules of actions at an intersection. In the abstraction stage, vehicles acquire high-level rules of actions in a region. Finally, we report simulation results and show the effectiveness of our algorithm.*

1 Introduction

In these years, the next-generation transport systems are eagerly developed with spread of IT technologies such as real-time positioning systems and small mobile terminals. However, most of behavioral decisions in these systems (e.g., which routes should be selected or which vehicles should be allocated) still depend on human-intensiveness (i.e., drivers). Therefore, we propose an algorithm for autonomous behavioral decisions of vehicles on the basis of a learning technique called ant colony heuristic.

Ant colony heuristic [1] is one of the heuristic algorithms for combinational optimization problems. Our algorithm consists of **learning** and **abstraction** stages. In the learning stage, vehicles acquire low-level behaviors (i.e, rules of actions at an intersection). Vehicles keep their transport histories (i.e., states and routes in the past). And, they leave pheromones on trails according to the transport histories. In the abstraction stage, vehicles acquire high-level behaviors (i.e, rules of actions in a region). In this stage, there are three steps: smoothing, filtering and estimating. The high-level behaviors are represented by transition probabilities among Voronoi regions called abstract road network.

2 Learning Stage

At first, we define the space of this transport problem. The space is given by a road network $G = (N, E), N = \{n_1, n_2, \cdots\}$. A node n represents a station where customers get on/off vehicles. An edge $e(n, n')$ represents to a route between nodes n and n'. We denote the quantity of pheromone on $e(n, n')$ as $Q(e(n, n'))$.

Vehicles are given by A in Equation (1). The vehicles have two roles in the problem space. One is transporting customers from their start to goal. The other is leaving pheromones on edges as hints to solve the problem for other ants.

$$A = \{a_1, a_2, a_3, \cdots\} \tag{1}$$

There are three states of vehicles: **empty**, **pick-up**, and **delivery**. At the empty, each vehicle follows trails of the pheromones on the problem space to find customer as early as possible. If the vehicle finds a customer, the state is changed to the pick-up. At the pick-up, the vehicle goes to the position of customer. After the pick up, the state is changed to delivery. At the delivery, the vehicle transports the customer to the goal. After the delivery, the state is changed back to the empty. Vehicles always store pairs

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of their states and traced nodes called **transport histories** in Figure 1. The transport history is a trigger to leave pheromones. If once the pheromone is left by the vehicle, the transport history is flushed.

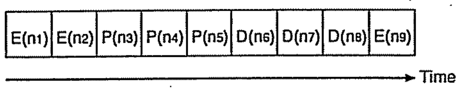


Figure 1. Transport history

There are two kinds of pheromones: **pick-up pheromone** and **delivery pheromone**. The pick-up pheromone is left on edges between nodes with pick-up state in the transport history. And, the pick-up pheromone leads vehicles to origins of customers (e.g., railway stations and department stores). The delivery pheromone is left on edges between nodes with delivery state in the transport history. And, the delivery pheromone controls entire flows of vehicles (i.e., location balancing of vehicles).

Here, consider the quantity of pheromones to be left. The maximum quantities for one ant are denoted by Q_p for the pick-up pheromone and Q_d for the delivery pheromone. The quantity of the pick-up pheromone q_p and delivery pheromone q_d for an edge is defined in Equation (2) and (3). $|E_p|$ is the length of edges in the trail, and α_p and α_d are weighting factors.

$$q_p = \alpha_p \cdot \frac{Q_p}{|E_p|} \tag{2}$$

$$q_d = \alpha_d \cdot Q_d \tag{3}$$

The update formula of quantity of pheromones for edge $e(n, n')$ is defined in Equation (4). β is an evaporation factor to adjust to dynamic changes of situations in the problem space.

$$Q(e(n,n'))_t = \beta \cdot Q(e(n,n'))_{t-1} + \sum_{a \in A}(q_p + q_d) \tag{4}$$

Consequently, the low-level rules of actions at a node are defined as roulette-select in Equation (5).

$$Pr(n,n') = \frac{Q(e(n,n'))}{\sum_{n'' \in link(n)} Q(e(n,n''))} \tag{5}$$

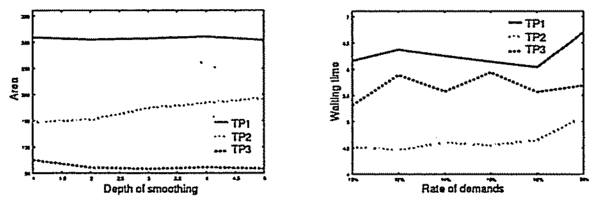
3 Abstraction Stage

The low-level rules of actions acquired in the learning stage are inadequate when the problem state is complicated. Such rules sometimes lead to unnatural behaviors for vehicles (e.g., moving backward and forward between nodes). Therefore, in the abstraction stage, the vehicles acquire high-level rules of actions in a region by the abstraction of pheromone distribution. The method of abstraction consists of three steps: **smoothing**, **filtering**, and **estimating**.

In the smoothing step, the pheromone distribution on the problem space is smoothed according to the depth of link nodes. In other words, the roughness is taken away from the surface of the pheromone distribution. The smoothing can highlight trends of customers hidden in the problem space. In the filtering step, distinct nodes called abstract nodes on the smoothed pheromones distribution are filtered. Such nodes are used as central points for Voronoi regions of the problem space called abstract road network. We adopted a simple simulated annealing algorithm to find the distinct nodes. In the estimating step, the transition probabilities among abstract nodes (i.e., they should go to another Voronoi region or wait current Voronoi region) are estimated by trial and error.

4 Experiments

There are three types of vehicles: TP1, TP2, and TP3. The difference among the three types is how to move at empty (TP1 is random-rules, TP2 is low-level rules, and TP3 is high-level rules). From the results in Figure 2, we can see that high-level rules produce effective circuit routes for vehicles at an empty state, but cooperation among vehicles will be required to decrease waiting time.



(a) Average of moving area (b) Average of waiting time

Figure 2. Experimental results

5 Conclusions

In this paper, we focused on behavioral decisions for empty transport vehicles. The results indicate that our algorithm can produce effective circuit routes for vehicles.

References

[1] M. Dorigo, V. Maniezzo, and A. Colorni. Ant system: Optimization by a colony of cooperating agents. *IEEE Trans. Sys., Man, Cybernetics*, 26(2):29–41, 1996.