Pheromone Model: Application to Traffic Congestion Prediction

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ABSTRACT

Social insects such as ants and bees perform complex tasks with pheromone communication despite lack of top-down style control. We have examined applications of this pheromone paradigm towards ITS. In this paper, a car is regarded as an insect that releases (electronic) pheromone that represents density of traffic. We propose a method to predict future traffic through a pheromone mechanism without resorting to the use of a traffic control center. We evaluate our method using a simulation based on actual traffic data and the results indicate applicability to traffic prediction.

Categories and Subject Descriptors

I.6.3 [**Simulation and Modeling**]: *Applications*

General Terms

Algorithms, Performance, Experimentation.

Keywords

Pheromone, traffic congestion prediction.

1. INTRODUCTION

Swarm intelligence is a new approach inspired by biological systems such as insects and is receiving attention in the AI field. Social insects perform complex tasks using decentralized communication based on pheromone. We will examine applications of this pheromone paradigm towards intelligent transportation systems (ITS).

Avoiding traffic congestion is a serious challenge with ITS. One of the key technologies to solve this problem is traffic (congestion) prediction. There exist traffic information systems which are actually used, such as VICS [1]. But such real-time information of the route will become outdated after a certain period. Traffic prediction can solve this problem by predicting appropriate traffic data for each stage of the route and reduce travel time to the destination. Traffic prediction techniques are widely studied in many institutions [3]. However, most of the studies use statistical data of the past. As such, it does not work sufficiently with sharp or irregular fluctuation of real traffic.

We propose a traffic prediction that uses a simple pheromone model that doesn not require statistical data. In our method, a car is regarded as an agent (or an ant). Each car would release some pheromone into a virtual space with its amount based on the congestion level. And the total pheromone amount after some transition will be used to predict the traffic in the future.

We evaluated the pheromone prediction method based on real traffic data [2]. The results indicate its applicability to prediction of traffic congestion in the immediate future.

2. MODELING FOR TRAFFIC SYSTEM

This paper proposes a traffic prediction pheromone model based on the model proposed by S. Brueckner [4]. Brueckner's Model is a kind of Coupled Map Lattice. We modified this model to be applicable to predict average link travel time of each of the road links. The following define detail transition functions that perform the prediction.

Each car releases (aggregates in place) pheromone according to congestion rate. (See Figure 1) Let aggregation of pheromone be r(t,p) in time t and a location p which corresponds to a link. Value v(t,p) is the speed of a car and α is the aggregation parameter. This function is represented as follows.

$$r(t,p) = \frac{\alpha}{v(t,p)}$$

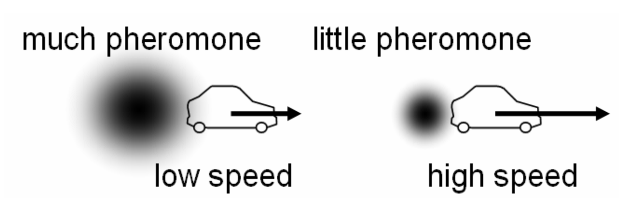

Figure 1 Aggregation of pheromone

Information servers are installed for every link and communicate with cars and neighboring information servers to maintain local pheromone dynamics. (See Figure.2) Note that these information servers might be virtual (e.g. variable in traffic center or car navigation client system, with cars serving as a temporary server with inter-vehicle networks [5]).

Let the amount of pheromone be s(t,p). The predicted amount of pheromone s(t+1,p) is represented in an equation as follows. Value E (0<E<1) is the evaporation parameter.

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$$s(t+1,p) = E \times s(t,p) + r(t,p) + q(t,p)$$

Transition function of the propagated amount q(t,p) is shown as follows.

$$q(t+1,p) = \sum_{p' \in N(p)} \frac{F}{|N(p)|} (r(t,p') + q(t,p'))$$

N(p) represents the upper stream neighbors of location p that affect the next status of location p. F is the propagation rate that is a function of the pheromone value of the upper stream in our model. The propagation rate function from a neighboring location p' to a location p is described as follows.

$$F = f(p,p') = \begin{cases} Fs & \text{when } p \text{ and } p' \text{ are on straight line} \\ \dfrac{Fs}{s(t,p)} & (s(t,p) > c) \\ F & \text{when } p \text{ and } p' \text{ aren't on straight line} \\ \dfrac{\gamma}{s(t,p)} & (s(t,p) > c) \end{cases}$$

Generally, more cars would proceed straight rather than turn right or turn left at a crossing. Thus, the propagation parameter is defined as $\beta \geq \gamma$. And we defined a congestion threshold c. When traffic congestion occurs down stream from p, propagation rate is an inverse proposition to the pheromone amount in p.

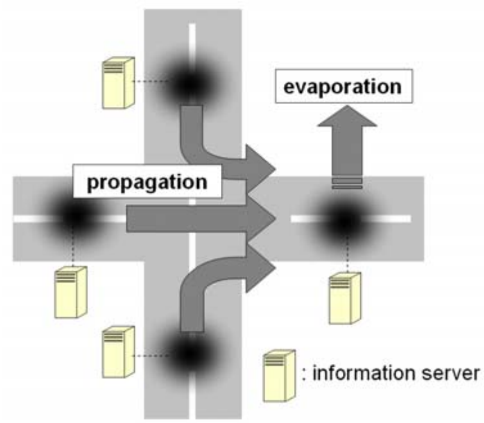

Figure 2 Evaporation and propagation of pheromone

Finally predicted link travel time is calculated by a scaling pheromone amount.

3. EVALUATION RESULT

We conducted a simulation of our model using actual traffic data [2]. Then we evaluated how accurate our model predicts traffic based on error indices. The prediction results are compared with "persistent prediction model" which assumes that the current situation will persist for some duration of time. Both prediction models predict traffic of 1 minute into the future.

Correlation coefficient and RMS error between predicted and actual travel time sequence is shown in Table 1. Both evaluations show that our method outperforms persistent prediction. Parameters here are determined as $\alpha = 2.0$, $E = 0.8$, $\beta = 0.8$, $\gamma = 0.1$, $c = 10.0$ and scaling parameter is 0.04.

Table 1 Precision of prediction

	Pheromone	Persistent
average correlation coefficient	0.59	0.41
average RMS error[sec]	45.6	56.5

Next we study the effect of different patterns of parameters. Optimal evaporation parameter was around 0.7 in our experiment.

Finally we apply the prediction results to the shortest route search. Table 3 shows percentage of selection of the right shortest route for each search. Result of the pheromone prediction method was better than the persistent prediction method.

Table 2 Shortest route search

	Right selection [%]
Pheromone	54.3
Persistent	36.2

4. CONCLUSION AND FUTUREWORK

This paper has proposed a traffic prediction method that employs the pheromone mechanism. Cars are regarded as agents that release pheromone towards roads. The pheromone would then evaporate and propagate according to a modified version of the state transition model proposed by S. Brueckner. According to the results of the experiments that used real traffic data, we confirmed the applicability of our method towards traffic prediction. Furthermore, we also confirmed optimal parameter settings through sensitivity analysis.

Future studies would include revealing the relationship between other parameter and prediction accuracy. Relationship between the optimal parameter and real data is also important in order to apply this method to the real world. Application towards congestion-aware shortest route selection might be improved by introducing negotiation algorithms since if all cars use the same algorithm, the optimal route may become congested. Swarm intelligence approach for shortest route search will realize global optimization of traffic system.

5. REFERENCES

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