Connected Vehicles Travel Time Prediction in a Scenario with Adaptive Traffic Light Control

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The paper is devoted to the short-term travel time prediction of individual connected vehicles in a regulated road network with adaptive control of traffic lights. The estimation of the total travel time combines both the travel time along road network links, obtained by a neural network model, and the waiting time at regulated intersections. At the first stage, it is proposed to use the model based on a neural network to estimate the travel time along the road links of the transportation network. At the second stage, the phase of the traffic light is predicted using the adaptive control method. Finally, the waiting time at the intersection is calculated based on the predicted arrival time of the vehicle at the intersection and the duration of the traffic light phase. Experimental results in a microscopic simulation environment allow us to conclude that the proposed approach outperforms baseline methods in terms of the mean absolute error criterion.

Proposed approach

The predicted travel time of the vehicle along the route is the *sum of the predicted travel time* along links of the road network and the *predicted waiting time* at the regulated intersection.

Travel time prediction

To estimate travel time of the vehicle along the road network link, it is proposed to use a model based on an artificial neural network (ANN). A feature vector for the ANN model:

- the distance from the current position of the vehicle to the intersection,
- the vehicle speed,
- the vehicle acceleration,
- the maximum allowed speed on the road network link,
- the number of vehicles in front of the selected one on the network link,
- the turn type at the intersection,
- the position and the speed of the first vehicle on the adjacent outgoing road link.

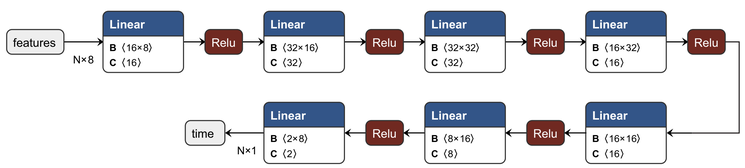

Figure 1: The architecture of the ANN model

We evaluate two approaches to calculate the travel time along the vehicle route.

Approach I

Two ANNs with the same architecture are trained: for road links adjacent to regulated and unregulated intersections. The ANN model trained on traffic data from regulated road links predicts travel time that implicitly contains the average waiting time at the intersection.

Approach II

The waiting time at the intersection is explicitly calculated according to the predicted phase of the traffic light and the phase duration . The ANN model is trained only for vehicles that are moving on the road link when the green light for that link is on (without waiting times).

Traffic light phase prediction

As adaptive control of traffic light phases, a method based on maximizing the predicted weighted flow of vehicles crossing an intersection at a selected traffic light phase is used.

Algorithm 1: Adaptive traffic light control method

Input data: $\tau_{\min}, t_p, p_{cur}, P$
Output data: p_{new}
if $t_p < \tau_{min}$ **then**
  $p_{new} = p_{cur}$;
  $t_p = t_p + 1$;
else
  $p_{new} = \text{argmax}\left(\{PredFlow\,(p) \text{ for } p \text{ in } P\}\right)$;
  $t_p = 0$;
end

In the algorithm, p_{new} is a new traffic light phase selected from a set of phases P of the considered traffic light, $\tau_{\min}$ is a phase switching interval, t_p is a duration of the current active phase p_{cur} of the considered traffic light.

The function $PredFlow\,(p)$ estimates the number of vehicles passing through the intersection during the specified time interval $\tau_{\min}$ according to the predicted travel times of vehicles.

Waiting time prediction

The estimate of the vehicle's waiting time at a regulated intersection is calculated from the duration of the predicted traffic light phase at the moment the vehicle arrives at the intersection. The traffic light is controlled by an adaptive traffic light control algorithm.

The waiting time at the intersection for each vehicle is equal to zero if the movement on the corresponding road link is allowed for the predicted traffic light phase. Otherwise, the waiting time is equal to the remaining duration of the traffic light phase.

Experiments

Simulation scenarios

- "Cologne-8" is a small urban area with 8 traffic lights.
- "Cologne-316" is a small traffic scenario that contains 2928 intersections of various topologies, including 316 regulated intersections.

Compared algorithms

- A deterministic model that predicts the travel time based on the analytical patterns of vehicle movement.
- ANNs that represent two models trained on traffic data for road links adjacent to regulated and unregulated intersections.
- ANN taking into account the waiting time.

Results

The proposed approach with the explicit waiting time calculation shows the best result according to the MAE criterion for both scenarios (Table I).

Table 1: Performance on traffic scenarios: average waiting time

Model	Scenarios	
	Cologne-8	Cologne-316
Deterministic model	13.88	65.73
ANN	7.92	26.25
ANN + waiting time	7.62	23.92

At the next step, the total accumulated travel time for all road links of the vehicle's route is compared. Figure 2 shows the dependence of the mean absolute error of the accumulated predicted travel time on the accumulated true travel time.

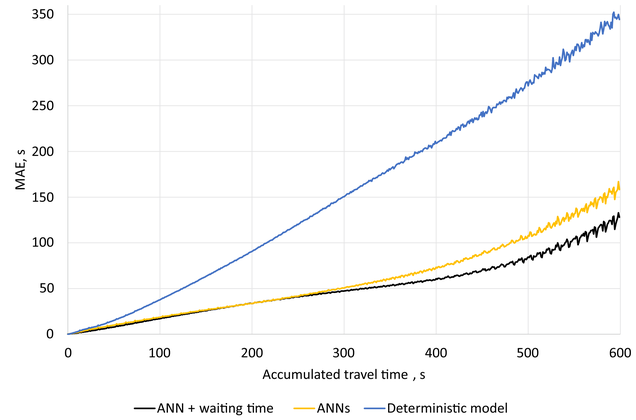

Figure 2: Comparison of the predicted and observed accumulated travel time

Conclusion

We consider the problem of predicting the travel time of movement of individual connected vehicles in a scenario with adaptive control of traffic lights. It is proposed to use the model based on a neural network to estimate the travel time along the road links of the transportation network, predict the traffic light phase using the adaptive control method, and estimate the waiting time at the intersection based on the predicted arrival time and the duration of the traffic light phase. According to the experimental results, the considered approach makes it possible to reduce the prediction error and to increase the accuracy compared to the baseline methods.

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