Travel Time Prediction Method for Expressway Using Toll Collection System Data

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SUMMARY

This paper proposes a travel time prediction method using toll collection system data such as the time a vehicle passes through an entrance and exit toll gate. The proposed method consists of a typical actual travel time calculation method using toll collection system data and a future travel time prediction method using travel time patterns. A future travel time prediction method is based on travel time pattern matching. Furthermore, the proposed method is verified by using actual field data. In Japan, toll collection systems are installed in most expressways. Therefore, by using the proposed method, travel time information can be provided for drivers at low cost and high precision in expressways without the need for sensors. The proposed method can be easily applied to ETC, because it uses only toll collection system data.

Introduction

In recent years, ITS-related research has been studied on a worldwide scale. In Japan, ITS-related research is being performed energetically in areas such as VICS and AHS. ITS research aims for efficiency, safety, and convenience. In the area of traffic control systems, research on traffic flow prediction and travel time calculation has been studied to improve efficiency and convenience. Travel time information has been identified as particularly important. Until now, travel time information has been calculated from sensor measurement results such as traffic counters and AVI systems installed on roads. Thus, it has been difficult to obtain for roads without sensors. For such roads, we developed a travel time calculation method using toll collection system data. Essentially, the desirable travel time information is a future travel time from an entrance toll gate to an exit toll gate. Therefore, we propose a method for predicting future travel time by using toll collection system data for roads without sensors. We can apply the proposed method at low cost to roads without sensors.

Object Road and Subjects

In this research, the object roads are toll roads such as expressways from which we can obtain toll collection system data including road entry/exit time data at toll gates, ID data of entered/exited toll gates, and kind-of-vehicle data (travel time can be calculated from toll gate entry/exit times). In Japan, expressways have service areas (hereunder, S.A.) or rest areas (hereunder, R.A.). When using toll collection system data, we have to overcome the following problems:

- There are many unusual data such as extremely long/short travel times
- There are some sections that have few data

However, these problems have been solved by past research, and we can estimate current travel times for roads without sensors by using toll collection system data. This research proposes a method for predicting future travel time by using these data. The data of the Tokyo-bound lanes of the Kan-Etsu Highway (from Hanazono to Nerima) was used to verify the validity of this method. The travel time information is for regular drivers who drive at normal speed.

Calculation of Typical Actual Travel Time

This chapter explains a method for calculating typical travel times by using toll collection system data. The travel times obtained from toll collection systems contain many unusual data and are distributed over a large area. Therefore, we must calculate a representative value of travel time of accumulated travel time data. This calculating method consists of removing unusual data and calculating the typical actual travel time. We classify unusual data into the following three types.

(TYPE-I):Extremely short travel time (motorcycles travel time in congested traffic, etc.)
(TYPE-II):Extremely long travel time (travel time of vehicles that have stopped a long time in SA or RA for rest purposes, etc.)
(TYPE-III):Data somewhat deviated from the distribution of travel time (travel time data of drivers who like driving at high or low speed, etc.)

Fig.1 shows examples of these unusual data.

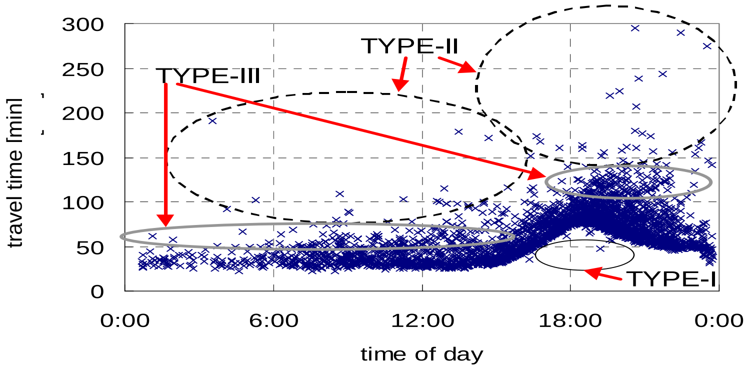
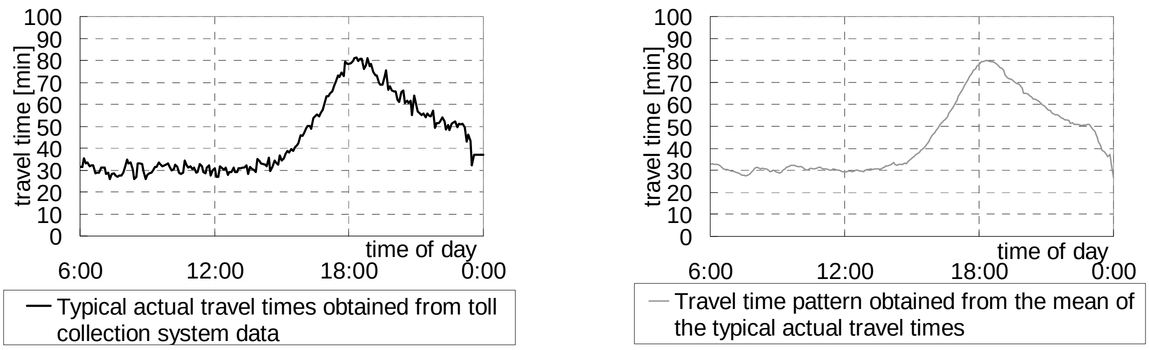


Fig.1 Examples of Unusual Travel Time

With regard to (TYPE-I) unusual data, it is enough to eliminate motorcycles' travel times in congested traffic. (TYPE-II) unusual data can be easily eliminated by performing a frequency analysis. (TYPE-III) unusual data can be determined by cluster analysis and then eliminated. After that we can eliminate unusual data of (TYPE-III). We used Otsu's Method to calculate a threshold for cluster analysis ([4]), and thus removed unusual data. Then the typical actual travel time was determined by calculating the average of the data after the removal.

Travel Time Pattern

After we removed unusual data from the toll collection system data, we derived the travel time pattern by using the typical actual travel times calculated from the toll collection system data. We consider the typical actual travel times as the travel times represented by a short time zone (ex.5 minutes accumulated data). However, as shown in Fig.2(a), the typical actual travel time of 1 day vibrates within a small range. This phenomenon adversely influences the pattern matching. Therefore, the mean of several typical actual travel time data was used to determine the travel time pattern. Fig.2(b) shows an example of the travel time pattern obtained from the mean of the typical actual travel time.



(a)the estimated travel time (b)travel time pattern

Fig.2 Example of travel time pattern

Travel Time Prediction

We propose a travel time prediction method based on travel time pattern matching by using an accumulated day pattern. Travel time patterns are accumulated for several months. Pattern matching is carried out in the following steps.

[STEP1] Square error calculation

Calculate the square error between the travel time pattern of the prediction day and all the accumulated travel time patterns.

[STEP2] Choose candidate pattern

Sum the square-error calculated at STEP1. Choose some candidate for the travel time pattern from those whose square error total is small.

[STEP3] Choose the 2nd-level pattern

Choose the 2nd-level pattern from the candidate pattern chosen in STEP2. There is a 2nd-level pattern in time zone from (n-1) hour to (n+1) hour (n is prediction time). If there is no pattern in the time zone, go to the next step.

[STEP4] Choose the final pattern

Choose the final pattern from the 2nd-level pattern. In choosing the final pattern, consider the condition of sections around the objective section of prediction. We consider that this final pattern is the most similar pattern.

[STEP5] Arrange the final pattern

Final pattern data are arranged on the basis of the time vehicles pass through an entrance toll gate. This is because the final pattern data are lined up on the basis of the time vehicles pass through the exit toll gate.

[STEP6] Obtain travel time prediction value

Obtain travel time prediction value by using the data obtained in STEP5. We consider that a travel time prediction value corresponds to the prediction time in the final pattern.

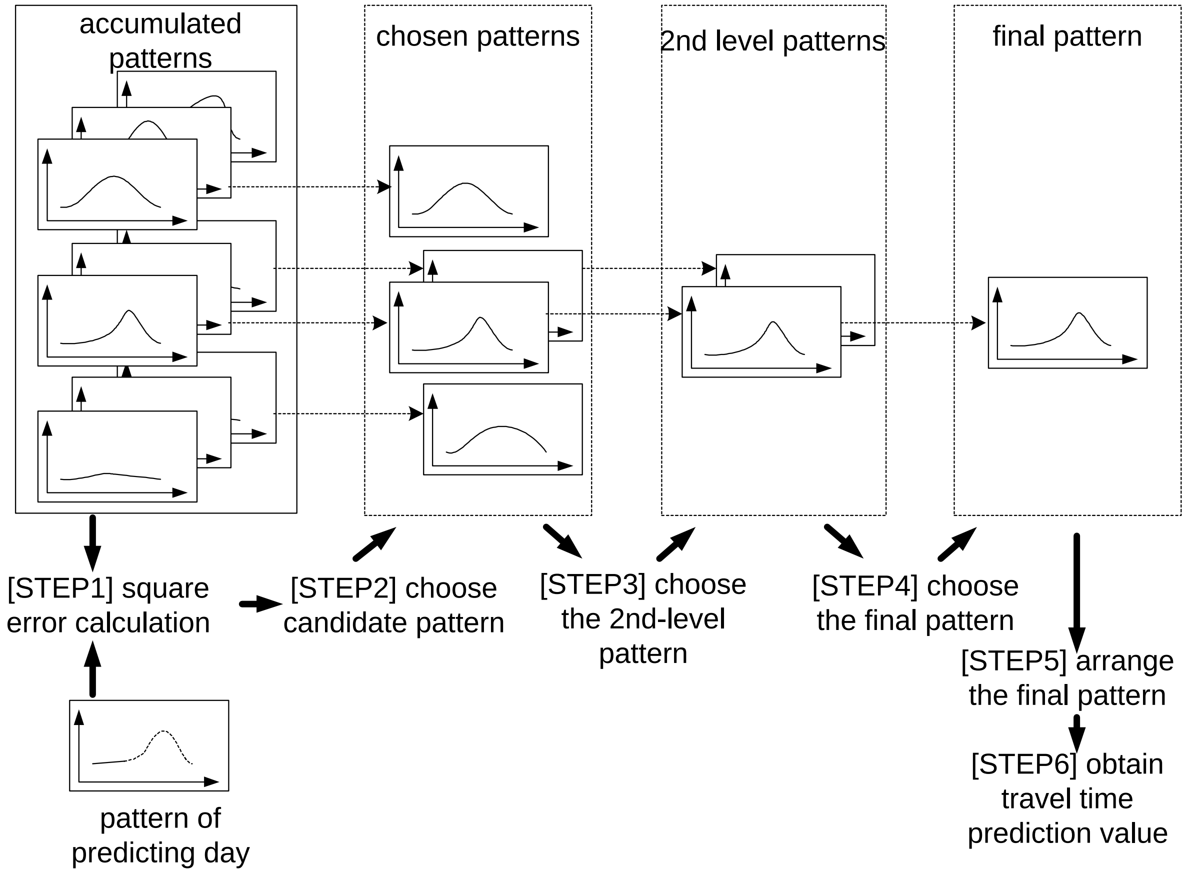
Fig.3(a) outlines the travel time prediction method and Fig.3(b) shows the concept of the travel time prediction system based on pattern matching.

Next, by using field data, we show an example of the prediction method based on pattern matching. In this case, the object road is the Kan-Etsu expressway. When we have operated pattern matching, we have used the accumulated data of 18 days of the same month (we have used the following patterns).

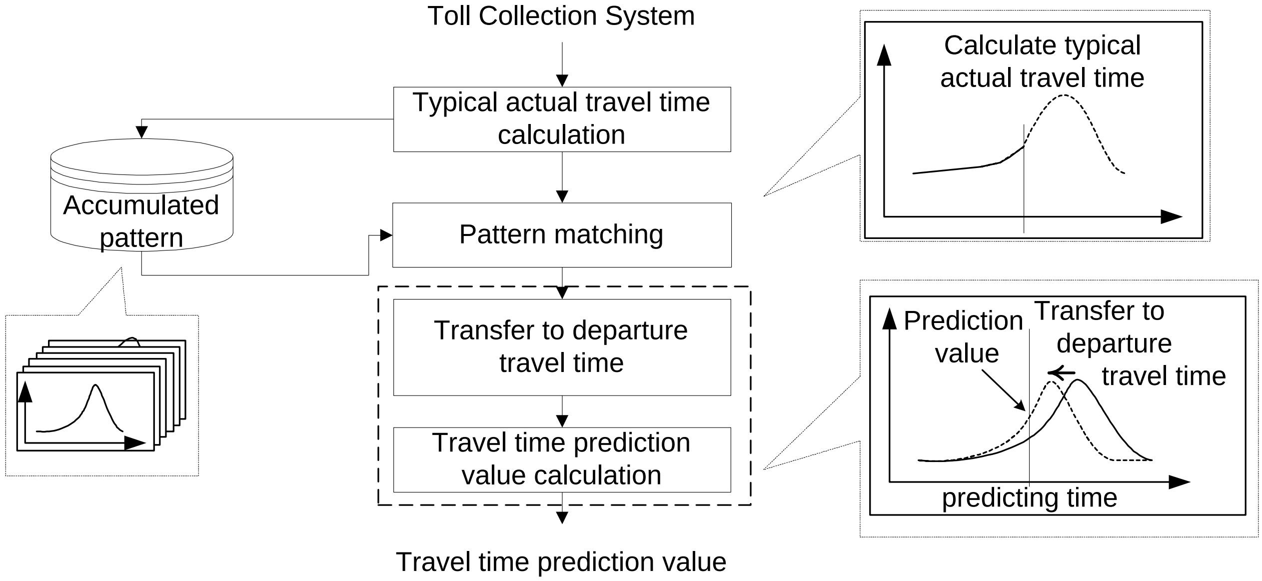
[Accumulated data used for pattern matching]

-Weekday : 10 patterns　　-Saturday : 2patterns

-Sunday : 4patterns　　-National holiday: 2ptterns



(a) Outline of travel time prediction method



(b) Outline of travel time prediction system

Fig.4 Concept of travel time prediction system based on pattern matching

Moreover, the length of the object road is about 56 km, and the object road has 2 service area and 1 rest area. Fig.4(a) shows the selected pattern by using this pattern matching method in this case.

Arrival travel time was predicted for two hours, as shown in Fig.4. We can predict some section travel times by using this method. It is possible to predict longer section travel times by using time-slice-method with the predicted section travel time. As a prediction proceeds for about two hours future time, this method accumulates error that cannot be ignored. This is because, as time proceeds, it is difficult to predict the traffic flow of newly entering vehicles. We are predicting arrival travel times for two hours in this prediction. Furthermore, Fig.4(b) shows the result of the prediction time.

As shown in Fig.4(b), we can obtain the prediction value with good precision during the time when a traffic congestion develops and unsnarls. However, there are some errors in the peak traffic congestion in this case. This is considered to be becsause there is no pattern onto accumulated patterns. Therefore, it is expected to be improved by increasing the number of accumulated patterns.

Conclusions

This paper has proposed a travel time prediction method using toll collection system data. Moreover, it has verified the proposed method by using actual data and verified its validity. With this method, we can calculate travel time prediction values at low cost in a road without sensors. In the future, we will develop a more effective method by combining the proposed method and traffic flow prediction theory. Furthermore, we hope to develop an application to ETC (Electric Toll Collection system) for the proposed method.

Acknowledgements

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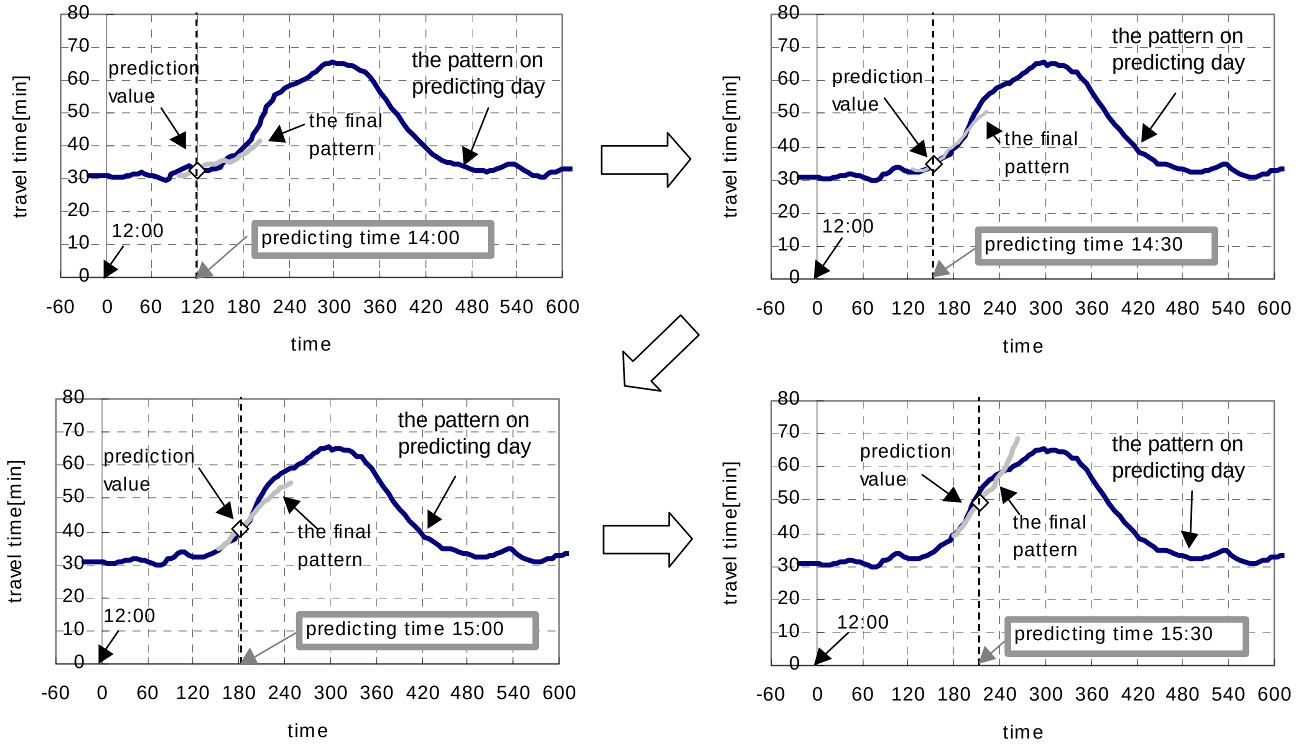
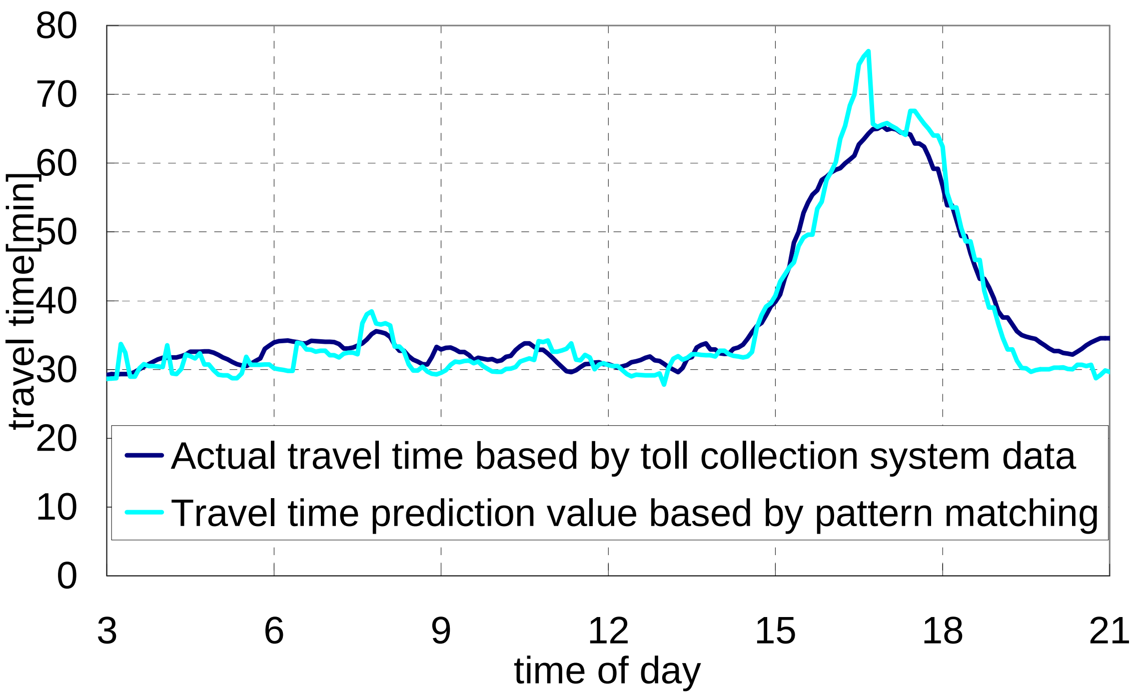


(a) A selected final pattern (Using Field Data of the Kan-Etsu Highway)



(b) Travel time prediction value based by pattern matching

Fig.6 Result of travel time prediction on a travel time pattern matching method

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