Development of the Probe Information Based System "PROROUTE"

YAO Enjian, SATO Akinori

Abstract

PROROUTE is a dynamic route guidance system based on the probe information, currently under development by the P-DRGS Consortium. It features route searches using road link travel time information, which is predicted with real-time probe data and accumulated database that is compiled based on previously collected probe car data. This paper introduces the two element technologies incorporated in PROROUTE in order to achieve highly accurate travel time prediction and route guidance performances. These are the NEC-original travel time prediction technique and the automatic updating function of the travel time accumulated database used as the basis for prediction and route guidance. In addition, the usefulness of the travel time prediction function will be demonstrated by evaluating travel time prediction accuracy for a specific road section.

Keywords

probe information, PROROUTE, travel time prediction, automatic updating of accumulated DB, route search

1. Introduction

The probe information enables the road traffic information to be processed by assuming that each vehicle acts as a sensor. The data transmitted from each vehicle to the center offers information on the route the vehicle passes. Compared to the main trunk roads with roadside sensors, the traffic status of more road sections may thus be identified in real-time.

Backed by the support of the Strategic Information and Communication R&D Promotion Programme (SCOPE) of the Ministry of Internal Affairs and Communications (MIE), the P-DRGS (Probe-vehicle based Dynamic Route Guidance System) Consortium was organized. This is an industry-university-government joint project involving NEC and other organizations including Nagoya University, Denso Corporation, Toyota MapMaster Incorporated, Japan Weather Association (JWA), A-Works Co. Ltd. and Liberra Corporation. It conducts R&D into application of the dynamic route guidance system, based on probe information in the Nagoya area [1]. This paper discusses the NEC-original travel time prediction technique and the automatic updating function of the link travel time accumulated database that supports travel time prediction and route guidance. These are the two element technologies incorporated in the dynamic route guidance system based on probe information "PROROUTE" being developed by the P-DRGS Consortium in order to achieve highly accurate travel time prediction and route guidance performances. In addition, this paper also introduces the results of an evaluation of the travel time prediction accuracy of a specific road section based on the actual travel time measured for the same section.

2. Outline of PROROUTE

PROROUTE is a system in which the center server searches the shortest route based on the start point, goal point and start time information input at the terminal (web, cellular phone, car navigation system, etc.) and provides the route information via the Internet [2].

Fig. 1 shows the system configuration of PROROUTE. This system utilizes four kinds of information including probe information provided by a taxi company, the current and future (up to 48 hours after) weather information provided by JWA, the public transportation information and regional information.

The road link travel time accumulated database updating system updates the travel time accumulated DB created based on previously collected probe data with real-time probe information. This enables continual improvement of the accuracy of the travel time accumulated DB by identifying long- and mid-term changes in the road traffic status caused by variations in road traffic that accompanies the socio-economic development. The travel time prediction system predicts the traffic status that varies every minute based on the travel

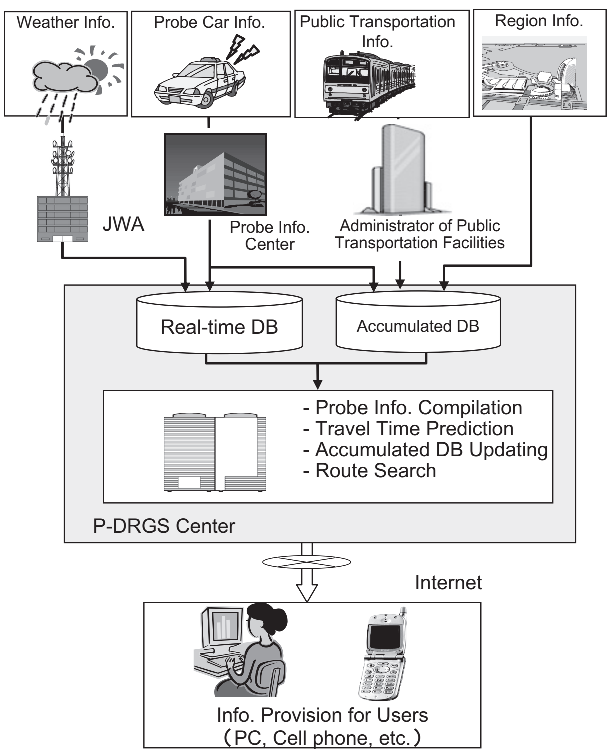

Fig. 1 PROROUTE system configuration.

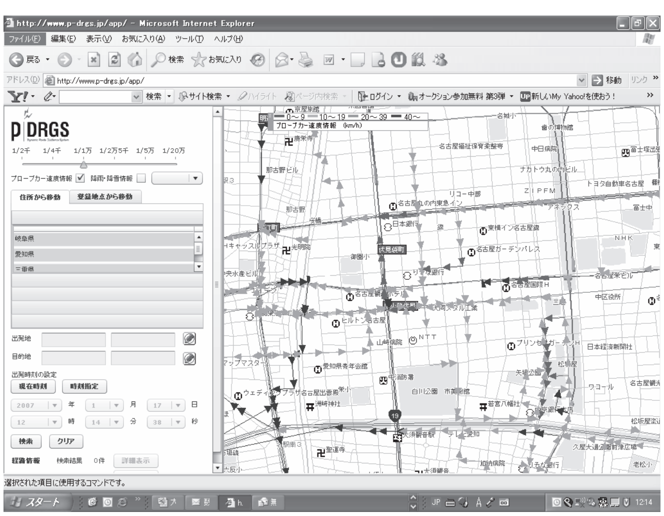

Fig. 2 Example of the PROROUTE system user display.

accumulated DB and real-time probe information. The present and future (up to 48 hours after) weather information provided by JWA is used to improve the accuracy of the generated travel time information by correcting the predicted travel time forecast in consideration of the reduced travel speed expected to result from the predicted rainfall. PROROUTE provides dynamic route guidance based on prediction results and achieves a multi-modal traffic route guidance service. In addition to vehicle route guidance information, users are provided with public transportation connection information.

Currently, probe data is collected from 1,700 taxi vehicles in Nagoya City and its surroundings and a route guidance service for these areas is available via PCs and cellular phone terminals. **Fig. 2** shows an example of the website displays provided for users of PROROUTE.

The travel time accumulated DB automatic updating system and the comprehensive travel time prediction system, both of which were developed by NEC, have been newly incorporated in the PROROUTE system of FY2007. We will describe the element technologies used in these systems in Section 3 below.

3. Automatic Updating of Travel Time Accumulated DB

3.1 Creation of Initial Travel Time Accumulated DB

The travel time accumulated DB of PROROUTE has been compiled by summarizing the probe data collected over the nine months from January to March 2002 and from October 2002 to March 2003 at appropriate time intervals, for each weather event (precipitation of ‘1mm and over’ or ‘not less than 1mm’), each day of the week and each holiday/weekday.

The link travel time accumulated DB compiled in this way reflects the basic patterns of daily traffic status changes (cyclic changes according to the day of the week and the time zone) and serves for the shortest route search and travel time prediction. The accuracy of the route guidance and travel time prediction is considered to depend on the degree by which the link travel time accumulated DB reflects the basic pattern of the road traffic status.

3.2 The Necessity for Updating the Travel Time Accumulated DB

The link travel time accumulated DB can reflect the cyclic changes of traffic status per season, day of the week and time zone, immediately after the collection of the data used in the database. Nevertheless, if the database is not updated periodically for a certain period, it would be unable to reflect the long- and mid-term changes in the road traffic status caused by variations in the road traffic accompanying the road conditions (changes in road networks, traffic restrictions, etc.) and in socio-economic development trends (changes in vehicle ownership rate, etc.). If the actual road status differs much from the link travel time accumulated database, it would be unavoidable that the accuracy of the road travel time prediction and route guidance would show deterioration.

In order to avoid this, the accumulated DB automatic updating system updates the link travel time accumulated DB periodically according to the real-time link travel time information collected more recently. This allows the accuracy of the travel time accumulated DB to be maintained and improved by automatically incorporating the long- and mid-term changes in the road traffic status caused by variations in socio-economic developments and road traffic volume.

3.3 Automatic Updating System of Travel Time Accumulated DB

Fig. 3 shows the configuration of the automatic updating system of travel time accumulated DB.

Automatic updating of link travel time accumulated DB is executed in the following steps:

1) The real-time data accumulation processing transforms the probe data collected sequentially into the real-time link travel time information of each vehicle and saves the information in the intermediate DB by classifying it per day of the week and per time zone.

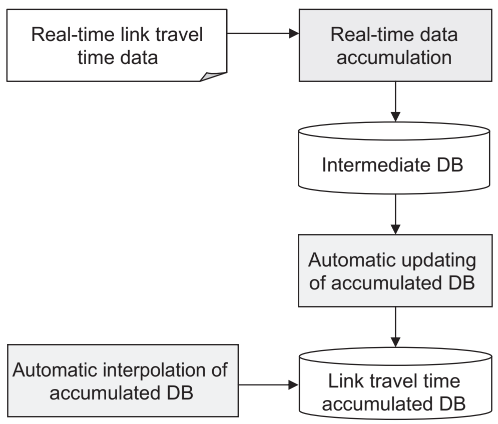

Fig. 3 System configuration of automatic updating of travel time accumulated DB functions.

2) The accumulated DB automatic updating processing checks the number of the per-day-of-the-week and per-time-zone data items saved in the intermediate DB at certain intervals. When the number is equal to or more than the previously set minimum sample size required for obtaining reliable information, the accumulated DB automatic updating function calculates the mean link travel time value, updates the accumulated DB using the mean value and deletes the data used in the mean value calculation from the intermediate DB [3). If the number of data items is below the minimum sample size required in order to obtain reliable information, the data is left in the intermediate DB and processed the next time that additional data is saved. Specifically, the link travel time in the accumulated DB is updated according to following formula (1).

$$T_i=\alpha \cdot t_i+(1-\alpha)\cdot T_{i-1}) \quad - (1)$$

Here, T_{i-1} is the link travel time before the updating of the accumulated DB in phase i (it indicates the initial accumulated DB when i = 1), t_i is the average link travel time calculated from the data in the intermediate DB, T_i is the link travel time after updating of the accumulated DB in phase i ,and α is the weighting coefficient $(0 \leqq \alpha \leqq 1)$. α is affected by the reliability of the initially compiled accumulated DB and the degree of long-term changes in traffic status. When α is large, the accumulated DB is updated with the weighting of the more recent data.

3) The accumulated DB automatic interpolation processing checks the updating time of the accumulated DB at certain intervals (every month, for example). When there is a time zone in which collection of real-time data is difficult, this processing interpolates its data using the travel time data in the adjacent time zones before and after the interpolated time zone by considering the continuity of the variations of travel time for the same link.

3.4 Effects of Travel Time Accumulated DB Automatic Updating

Automatic updating of the link travel time accumulated DB makes it possible to avoid the troublesome manual database updating, to incorporate the long- and mid-term changes in the road traffic status caused by actual socio-economic development and changes in traffic patterns and improve the accuracy of the accumulated DB over the years after the compilation, but without stopping the system operation. Furthermore, it also makes it possible to collect raw data of areas for which not much probe data has been collected in advance and to automatically build the accumulated DBs in these areas, thereby hastening the practical implementation of the probe systems for them.

With regard to the improvement of the travel time prediction and route search accuracy brought about by the accumulated DB automatic updating system, evaluation has not yet been performed as it is still less than a month since the system was introduced in PROROUTE and the travel time accumulated DB is not as yet updated enough. We are planning to verify the effect of accumulated DB automatic updating in the future by separately performing travel time prediction and route guidance. This will be done by using the DB before updating as well as that updated with the travel time and route search information obtained from actual experimentation. We may thus usefully compare the two sets of travel time and the route search results.

4. Comprehensive Travel Time Prediction Technique

Although the travel time accumulated DB can be used to predict the travel time due to normal changes in the traffic status, road works and traffic restrictions may be experienced in various places every day. Unexpected events such as traffic accidents are also frequently met with. Therefore, in order to provide the shortest route and travel time information according to the current traffic status, it is essential to predict the link travel time by adding the real-time traffic information in the road network.

As the PROROUTE terminal is designed to be capable of setting the start time at a desired interval after the current time, the travel time prediction system should be able to offer any of the short-term (from the present to 30 minutes after), mid-term (from 30 minutes after until 180 minutes after) and long-term (180 minutes or more after the present) predictions. In addition, it should also be able to predict the travel time accurately even when the current traffic status is deviated from the basic pattern of normal traffic status change due to road works, a traffic accident, or a traffic restriction.

4.1 Framework of Comprehensive Travel Time Prediction Technique

Our comprehensive travel time prediction technique can achieve the travel time prediction with high accuracy by

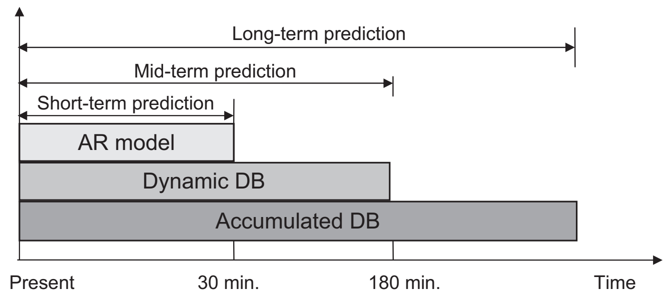

Fig. 4 Framework of comprehensive travel time prediction.

automatically selecting the optimum prediction model according to any traffic status (traffic congestion level) and prediction condition (short-term, mid-term or long-term) [4)]. **Fig. 4** shows the framework of the comprehensive travel time prediction technique.

This technique describes the variations in traffic status within 30 minutes of the present using the accumulated DB expressing the cyclic change and a time-series model expressing temporary variations (such as the multi-AR (Auto Regressive) model). However, if the traffic status changes more significantly than usual, the AR model is not enough to express the difference from the cyclic change. In this case, it is required to ensure the prediction accuracy by using dynamic DB to identify the overall change in the traffic status.

The mid-term prediction of traffic status is performed with an observational skill that can reproduce a similar traffic status under the same event conditions (day of the week, time zone, weather, etc.) in the dynamic DB after pattern change or in the accumulated DB.

The long-term prediction of traffic status is performed from the data of the same event conditions (day of the week, time zone, weather, etc.) in the accumulated DB.

4.2 Travel Time Prediction Model

1) Multiplex AR Model

With the above described framework, the short-term prediction may use either "accumulated DB + AR" or "dynamic DB + AR."

$$x_t = \sum_{m=1}^{k} a_m x_{t-m} + \varepsilon_t \quad - (2)$$

Here, x_t is the one-dimensional time-series data with an expected value of 0 and represents the difference between the real-time probe data and the link travel time in the accumulated DB, a_m is a parameter, ε_t is the error term, and k

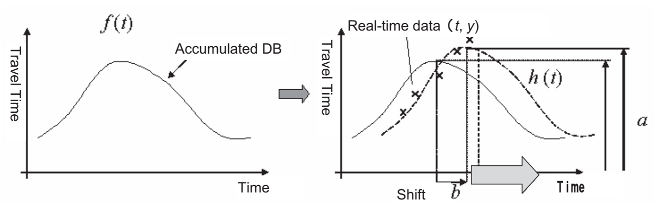

Fig. 5 Transformation from accumulated DB to dynamic DB.

is the order of the multiplex AR model [5)] that is set using the data of the past 30 minutes.

2) Dynamic DB

As described above, if the traffic status changes more than usual, the AR model predicting the fluctuation component is not enough to represent the difference from the cyclic changes. In such a case, creating a DB that is better in approaching the real time traffic status than the accumulated DB may make it possible to assure the prediction accuracy. **Fig. 5** shows the transformation of the accumulated DB curve into a dynamic DB for a link to make the travel time in dynamic DB closer to the real-time data. The transformation function $h_{(t)}$ in this figure can be expressed with formula (3) below.

$$h(t \mid a, b) = af(t - b) \quad - (3)$$

Here, $f_{(t)}$ is the accumulated DB, a and b are parameters (a is the magnification factor and b is the deviated time), and t is the time. a and b can be estimated by the minimizing formula (4).

$$L(a,b) = \sum_{i=1}^{n} exp(-\alpha(t_c - t_i))(y_i - h(t_i \mid a,b))^2$$

$$+w_a(1 - a)^2 + w_b b^2 \quad - (4)$$

Here, α , w_a and w_b are positive constants, y_i is the real-time travel time, t_c is the current time and n is the number of data items in a certain time period in the past.

4.3 Verification of the Travel Time Prediction Accuracy

The comprehensive travel time prediction technique achieves travel time prediction of high accuracy by selecting the optimum model according to the prediction condition from short-term to long-term and the current traffic status. We verified its accuracy by installing AVI (Automatic Vehicle Identification) cameras in three positions on the Nagoya-Nagakute road, measured the travel time values of the two road sections, and compared the results with the results predicted by the travel time prediction system.

As a result, we were able to confirm that accurate prediction is possible under any traffic status, with a prediction error for the short-term prediction (5 to 30 minutes after) of less than 16.1% and that for the mid-term prediction (30 to 90 minutes after) of less than 25.6%.

5. Conclusion

In the above, we have summarized two functions of the PROROUTE probe information-based route guidance system. These are the travel time prediction function that is critical for highly accurate route guidance performance and the automatic updating function of the travel time accumulated DB used as the basis of the travel time prediction and route search and have also evaluated the accuracy of travel time prediction using AVI data.

The link travel time accumulated DB automatic updating system can cause the troublesome manual database updating to be unnecessary and is expected to maintain or improve the accuracy of the accumulated DB by incorporating long- and mid-term changes in road traffic status caused by socio-economic development and changes in traffic volumes.

The comprehensive travel time prediction technique selects the accumulated DB or the dynamic DB and the travel time prediction model based on these DBs and the AR model according to the traffic status and prediction condition. Accurate travel time prediction is thus achieved by reducing short- and mid-term prediction errors to below 16.1% and 25.6% respectively.

In the future, we will compare the travel time and route search data measured in experiments using actual vehicles with two sets of results predicted by using the accumulated DB before and after updating. We will then evaluate the accuracy improvements that are effected by the automatics accumulated DB updating.

In closing, we would like to express our gratitude toward the members of the P-DRGS Consortium for their kind support for the present study.

*PROROUTE is a registered trademark (under application) of the P-DRGS Consortium.

*As the products introduced in this paper are mainly sold for the domestic market, some figures feature explanations by the Japanese Language.

References

1) P-DRGS website.
http://www.p-drgs.com/
2) MORIKAWA Takayuki, et al.: "DOTEKI KEIRO ANNNAI SISUTEMU 'PRONAVI' NO KAIHATSU TO SEINO HYOKA JIKKEN (Development and Performance Evaluation Experiment of Dynamic Route Guidance System 'PRONAVI')," KOTSU KOGAKU (Journal of Japan Society of Traffic Engineers), Vol. 42, No. 3, 2007.
3) YAO Enjian, et al.: "KOTSU JOHO SEISEI NI OKERU AVI SAISHO SANPURU-SUU NI KANSURU KENKYU (Study on Minimum Sample Size for Traffic Information Generation)," 5th ITS Symposium, (CD-ROM), 2006.
4) FUJITA Takashi, YAO Enjian et al.: Travel Time Prediction Using Probe-Car Data, Proc. Of the 13th World Congress on ITS, London, 2006.
5) NAKATA T. and TAKEUCHI J.: Mining Traffic Data from Probe-Car System for Travel Time Prediction, Proc. of the 10th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, ACM Press (KDD2004), 2004.

Authors' Profiles

YAO Enjian
Assistant Manager,
ITS Business Promotion Center,
Broadcast and Control Systems Operations Unit,
NEC Corporation

SATO Akinori
Senior Manager,
ITS Business Promotion Center,
Broadcast and Control Systems Operations Unit,
NEC Corporation