A Study on Prediction of Travel Time over Intervals between Adjacent Bus Stops Using Probe Data.

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（別紙様式 2）

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論 文 名　　：A Study on Prediction of Travel Time over Intervals between Adjacent Bus Stops Using Probe Data.
(プローブデータを利用した隣接バス停間の移動時間予測に関する研究)

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論 文 内 容 の 要 旨

Prediction of travel time over travel routes is an important factor for many people who travel or commute, especially using the public bus services. Mostly, people consider travel time as well as stochastic factors in several time periods such as dwell time, traffic congestion, accidents, and so on. They usually prefer to minimize the time spent traveling from their origin to destination by choosing the best route. Intelligent Transportation Systems (ITSs) have recently been widely used in planning, evaluation and control of the reliability of the public transportation system. One of the evolutions in ITSs is largely related to bus probe data. Probe data, which are generated by vehicles, include data obtainable from navigation systems, such as time and position (longitude and latitude), i.e. data on the vehicle's running and performance history. In addition, using bus probe data enables us to monitor the state of road traffic characteristics and to measure the reliability of and variability in travel times of public bus services.

In this research, I have proposed nonlinear dynamical methods for predicting bus travel time over each interval between adjacent bus stops for seven and eight time periods in a day. The proposed methods basically utilize time series methods based on machine learning techniques: Artificial Neural Network (ANN), Support Vector Machine (SVM) and Random Forest (RF). For this purpose, at first, I classified intervals between adjacent bus stops into two classes: stable and unstable. Then I identified two statistically significant factors: variabilities in travel time in the same time periods over days and correlations of travel time between eight time periods, which influence bus travel time over unstable intervals in the current time period. I conducted experiments to evaluate our proposed methods. I have used real bus probe data collected from November 21st to December 20th, 2013 and provided by Nishitetsu Bus Company, Fukuoka, Japan.

I summarize the results obtained in this research as follows:

- Chapter 1 describes background information concerning Intelligent Transportation System (ITSs), including Bus Probe Data as a robust data source for predicting bus travel time, problem formulation, uniqueness of this research, the framework and the objectives of this research.
- Chapter 2 presents a literature review regarding prediction of bus travel time. A variety of models and algorithms have been developed to predict bus arrival times or bus travel times, and these can be classified into the following categories: historical average models, regression/time series models, and machine learning techniques including Artificial Neural Network (ANN) Support Vector Machine (SVM) and Random Forest (RF).

- Chapter 3 explains the data used in this research, describes the preliminary data preparation for the analyses and the methods used in prediction models. In addition, I describe how real-world bus probe data can be utilized, what kind of analytic results are obtained, how the data should be calculated and what kind of challenges are involved when handling this bus probe data.
- Chapter 4 discusses some of the highlighted analytic results generated from the probe data. I first calculated the bus travel time over each interval between adjacent bus stops. Then, I distinguished the intervals into stable or unstable ones. Next, I conducted statistical analysis on travel time especially over unstable intervals considering the variations in the travel time between different time periods in a day, in the same time periods over the past days and the correlation of travel time between adjacent time periods in a day. Based on the results of these analyses, I employed two types of input data: Dynamic Average Travel Time (DATT) and Historical average travel time (HATT). DATT denotes the average travel time in the time period right before the current one. Introducing DATT can be expected to adjust the error in predicting travel time in the current time period using the travel time observed in the period just before the current time period. HATT denotes the average travel time in the same time period during the past several days. It is a very important input variable of the model because HATT is more effective when travel time tends to be more consistent over days.
- Chapter 5 proposes nonlinear dynamical models for predicting bus travel times using historical information. I developed time series prediction models based on Artificial Neural Network (ANN), Support Vector Machine (SVM) and Random Forest (RF) to predict travel time over unstable intervals. Focusing on recurrent and non-recurrent variabilities in travel time over the unstable intervals, I predicted travel time for seven time periods in a day (omitting EM) and compared the experimental results of the various approaches.
- Chapter 6 proposes a different approach for predicting bus travel time considering traffic congestion. This approach uses two input variables, DATT and HATT, selectively with a distinction between peak-hour and off-peak periods.
- Chapter 7 defines the role of these approaches in the evaluation of the performance of the prediction models. I compare the proposed model mentioned in Chapter 6 with the model mentioned in Chapter 5. In addition, to measure the significant effects of variables other than the single independent variable, I conduct an experiment comparing our models and the model proposed by another study.
- Finally, I conclude the thesis in Chapter 8. I describe the results of experiments and the findings of this research, contribution and discuss some topics for future scientific research in the prediction bus travel time.