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Fusion of travel time data in Niayesh tunnel using Bayesian inference

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ABSTRACT: As data collection costs decrease, transportation systems have shifted from systems requiring data to systems requiring data analysis. Since the accuracy of these data varies with the sources of data collection, acquiring higher-accuracy data from a combination of multiple sources is the main challenge of working with such data. Data fusion is a very efficient mechanism that can interconnect data from different sources to increase the accuracy of data in line with the purpose of the study. The main goal of this article is to get the most accurate travel time possible from multiple sources. Among the data fusion methods are the Kalman filter, Bayesian inference, artificial neural networks and Dumpster-Scheffer theory, from which the Bayesian inference is used, and its results are investigated. It is proposed that by combining different data sources with different temporal and spatial coverage, the most accurate travel time with maximum spatial and temporal coverage would be achieved. The Niayesh tunnel in Tehran was selected as a case study, where extensive equipment for intelligent transportation systems is installed. In this study, considering the possibility of simultaneous access to multiple data sources at the same location, the following source, Google travel time data, Bluetooth travel time data and Inductive loop detectors, were fused. The improved travel time can increase the accuracy of travel time costs in transportation planning, information on variable message signs and routing software.

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1. INTRODUCTION

In order to truly understand the state of the network, traffic control and evaluation of network performance, the collection and analysis of traffic data is a basic requirement. Good quality traffic information is essential to improve traffic models that contribute to short-term planning and regional policies. The proposal for this project is to combine information obtained from fixed & mobile sensors using data fusion techniques that can provide a complete picture of what we need. Data fusion (DF) is a set of techniques that uses statistical methods to combine information from different sources in order to reach a better inference. It is useful to use data fusion techniques to predict the situation as well as provide accurate network performance indicators because predicting these indicators plays an effective role in traffic. Van et al. [1] used a linear fitting model to predict travel time by combining Loop Detector data and floating machine data. They showed that linear fit on current, measurements of occupancy, travel time, and day of the week are useful for short-term forecasting of travel time. For long-term forecasts, however, the use of historical data will be more effective. Hillman et al. [2] also estimated travel time using the Kalman filter and travel time fusion from local sensors and electronic toll data. The results showed that travel time estimation using data fusion methods is better than estimated travel time from each data source alone. Among the existing methods for data fusion, it can be concluded that Bayesian inference is a logical and valid method for data fusion. Studies have shown that more than two data sources have been used in only three studies. On the other hand, none of the studies used Google data, and in this research, Google travel time data has been used as a new and suggested source.

2. METHODOLOGY

Bayesian inference is a probability-based method. This method is based on the principle that for each quantity, there is a probability distribution that by observing new data and reasoning about its probability distribution, optimal decisions can be made. This theorem is useful in that it can be used to calculate the probability of an event by making it conditional on the occurrence or non-occurrence of another event. In many cases, it isn't easy to calculate the probability of an incident directly. Using this theorem and conditioning one event on another, the required probability can be calculated. The main reason for choosing the Bayesian method in this article is that the Bayesian method has good accuracy despite its simplicity. One of the main advantages of this method is the use of the anterior distribution, which

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Table 1. Comparison of the square root of the errors in different sources

Sensors	Bluetooth	Google	Loop Detector 1	Loop Detector 2
RMSE	212	335	602	614

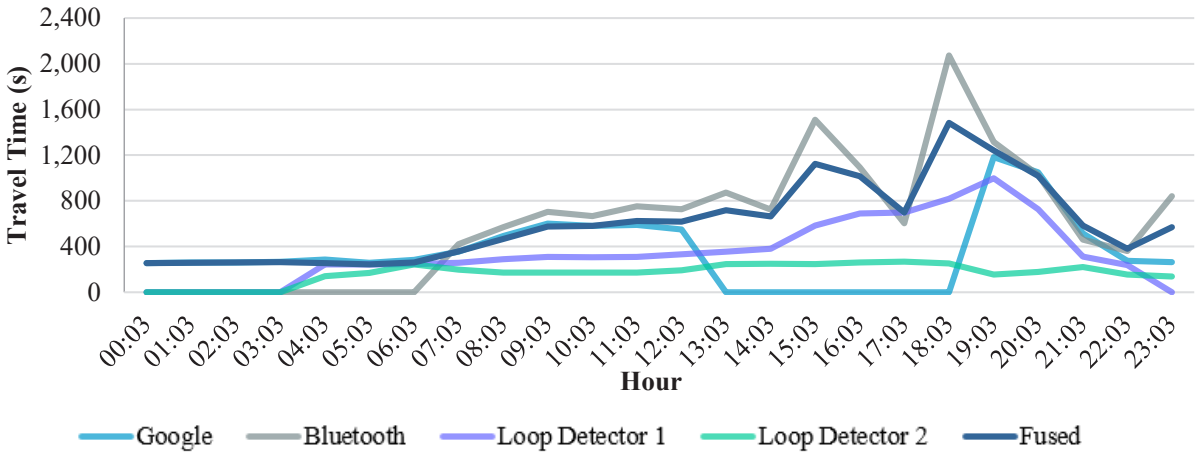

Fig. 1. Comparison chart of resource travel time

due to the lack of sensor data in some time intervals, this model uses a pre-distribution to consider a value for that interval [3].

3. RESULTS AND DISCUSSION

Considering the coverage area of each intelligent system, the Niayesh tunnel was selected as a place where several sources of traffic information are available simultaneously for a case study. Among the available technologies, the following data for the north and south tunnels of Niayesh are the information recorded by the monitoring system via Google, Bluetooth and traffic loop detector. RMSE index is used to compare the results of the study with reality and is one of the most widely used indicators in assessing the accuracy of the results.

$$\mathbf{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \widehat{x_i}\right)^2} \qquad (1)$$

In order to merge the data, the travel time accuracy of the sensors is calculated and the error of different sources relative to each other is shown in Table 1.

Finally, the travel time obtained by separate and fused sensors is Fig. 1:

4. CONCLUSION

The results show that first, fusion is easily available if data is available from two sources (Google and Bluetooth), three sources (Google, Bluetooth and Loop Identifier 1), or four sources (Google, Bluetooth, Loop Detector 1 and Loop Detector 2). Second, the answers are close to the less error-prone Bluetooth source. Because Bluetooth is not available at all times and, for example, no Bluetooth data is available at midnight, this sensor has limited time coverage but full spatial coverage. On the other hand, because the Loop Detector is only available at the beginning and end of the tunnel, the information is only available at limited points along the route, and as a result, it has limited spatial coverage, but full temporal coverage. The combination of these two sensors with fusion models makes the final results have complete spatial and temporal coverage. The results of the hypothetical data show that the travel time output of the fusion models has higher accuracy than the travel time obtained from each of those sensors separately. This comparison has been investigated as the root mean square error (RMSE), and its results are shown in Table 1. Because fused travel time has higher accuracy than individual sensors, it can help to improve all travel time applications in the operation of the transportation network.

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