CREATING AN INTELLIGENT TRANSPORTATION SYSTEM FOR SMART CITIES: PERFORMANCE EVALUATION OF SPATIAL – TEMPORAL ALGORITHMS FOR TRAFFIC PREDICTION

LAKAKIS K. and KYRIAKOU K.

Department of Civil Engineering, Aristotle University of Thessaloniki, 54006, Thessaloniki, Greece
E-mail: kyriako@civil.auth.gr, Tel +30 2310304644, Fax: +302310304644

ABSTRACT

Traffic congestion is a problem that predominates in urban areas and costs money and time. For instance, traffic congestion in the United States in 2009 costs commuters 4,8 billion hours of travel delay and U.S 115 billion on opportunity cost and fuel costs. Urban traffic congestion also brings broader societal impacts such as pollution and carbon dioxide emission, micro-climate change and urban heat islands. For these reasons, last years it is intensively tried to create smart cities through intelligent urban transportations. A traffic prediction system that will predict travel times and navigate the drivers according to travel times can help to maintain a high level of operational efficiency in transportation system.

The aim of the current study is to investigate mathematical spatial - temporal algorithms aiming at the optimum algorithm for travel time prediction in the urban area of Thesssaloniki. Thessaloniki is the second biggest city in Greece and has traffic congestion problems. Traffic congestion is more intense in the center of the city where many land uses are concentrated. Historic data will be used for prediction provided from taxi's GPS receivers. As they travel along the road network they provide with a large amount of GPS points giving vehicle's ID, vehicle's coordinates, velocity, orientation, time and date during all the day for every single day. Implementing a map-matching process, travel time data will be leaded out. Then it will be possible to implement different algorithms such as Artificial Neural Networks and Kalman Filter, to predict travel times.

The predictions will be evaluated with tracked times. Some measures will be defined for the assessment of algorithms such as Mean Absolute Error (MAE) and Mean Square Error (MSE). Software such as ArcGIS and Matlab will be precious tools in order to carry out the study.

The contribution of this study can be described in terms of smart cities and intelligent transportation systems but also as a decision support system that enable the city to better plan emergency management response during earthquakes, floods etc.

Keywords: smart navigation system**,** traffic prediction, and performance evaluation

1. Introduction

Urban traffic congestion is a problem that adversely affects the quality of life. This problem predominates in larger cities where the demand of transportation is continuously augmented and it is not possible to extend the transportation infrastructures because of lack of space and the cost. The negative effects such as deterioration of environment quality, time and associated cost are significant enough. One significant way to increase the transport efficiency and reduce the traffic congestion effectively is to implement a system for traffic guidance and control. This system could be more effective if it could predict the traffic flow in order to navigate the user according to traffic conditions. Traffic flow prediction has been regarded as a critical concern for intelligent transportation system (ITS). Traffic prediction supports the development of traffic control strategies in advanced traffic managements systems ATMSs and real-time route guidance in advanced traveler information systems (ATISs). So the necessity to have a continuously update prediction of traffic condition is of utmost important. These predictions could be incorporated in navigation systems aiming at one advance navigation system that could predict the crowded routes and propose the optimum route by estimating the travel time.

In the current study, it is investigated the performance of two of the most wide used algorithms for traffic prediction, Kalman Filter and Artificial Neural Networks. The required traffic data have been provided by taxi-vehicles which use GPS receivers in order to navigate in the city. The taxis travel every single day without any restriction for the needs of current study. The study was performed for the urban area of Thessaloniki, the second biggest city in Greece where the traffic congestion is one of the most significant problems for the inhabitants.

2. Materials and methods

The methodology is divided into the two following stages. The stage 1 includes the concentration, selection, and exclusion of GPS points in order to be feasible to calculate the travel times. This methodology has been analyzed minutely in previous studies by the same authors. For this reason it will be presented at the current study a table where stage 1 is briefly described. At stage 2, it is used the data from stage 1 in order to predict travel times with two different algorithms.

2.1. Travel Time Calculation

In the following table it is defined the 6 phases to calculate the travel times. It is also described process, tools and results. Precious tool for this study is the ArcGIS software and Matlab where the authors have code short applications for the needs of the study.

Table 1: Process to calculate the travel times

Ph.	Process	Tools / Software	Outcome
1	Collection of GPS points	ArcGIS Excel	TAXIS' ID, coordinates, velocity, orientation, time and date
2	Division of Tsimiski road to segments starting and ending at nodes with traffic lights	ArcGIS	11 segments with different lengths
3	Assignment of GPS points to Tsimiski road with the criteria of distance and orientation	ArcGIS	Points only for Tsimiski Road
4	Map-Matching process using a linear regression model and its prediction zone	MATLAB	Points spatially referenced
5	Travel Time Calculation Process: 1. Identifying TAXI's ID that is appeared among the road at least twice 2. Points selection with same ID at the same period of day 3. Calculation of travel time from p to p+1 4. Exclusion of travel time more than 4m min for 200m distance 5. Calculation of travelled distance	MATLAB	Travel times per segment
6	Definition of homogenous time zones according to travel purpose (shops, entertainment, offices, services, houses)	MATLAB	7 Homogenous time periods

All the available GPS points have been classified according to the above procedure in order to implement the following algorithms.

2.2 Travel Time Prediction

Kalman Filter

Kalman Filter is a set of mathematical equations that implement a predictor-corrector type estimator. The whole process is briefly described from the two following steps "Measurement

Update – Correction" and "Time Update – Prediction". The procedure is repeated for each time step using the state of previous time as an initial value. Therefore the Kalman Filter is called a recursive filter. In previous studies it has been studied the performance of Kalman Filter with or without parameters and it was figured out that the performance was improved with parameters. So in this study it is tested the performance having as parameters the weekday, time period and homogenous time zone.

Artificial Neural Networks

Neural networks are statistical models of real world systems that are built defining a set of parameters. These parameters function as inputs that are associated to a set of values, the outputs. The process of tuning the weights to the correct values – training – is carried out by passing a set of examples of input-output pairs through the model and adjusting the weights in order to minimize the error between the answer the network gives and the desired output. Once the weights have been set, the model can produce answers for input values that were not included in the training data. The models do not refer to the training data after they have been trained; in this sense they are a functional summary of the training data. In order to build the optimum network for the current study, 10 architectures were tested and with the criterion of Mean Square Error (MSE) and Mean Absolute Error (MAE) it was selected the fleet one. Weekdays, homogenous time zones and time period are used as parameters to optimize the model. All trials are presented at the table 2.

Table 2: ANN Architectures and performances

Trial No	No of hidden neurons	Final MSE	Final MAE
Train 1	3	0,000000000038308	0,000000254151920
Train 2	4	0,000000000025486	0,000000158829056
Train 3	5	0,000000000058978	0,000000209284720
Train 4	6	0,000000000006739	0,000000103325239
Train 5	7	0,000000000035821	0,000000159456946
Train 6	8	0,000000000080679	0,000000289298069
Train 7	9	0,000000000004524	0,000000052141749
Train 8	10	0,000000000740195	0,000016667886634
Train 9	15	0,000000002534557	0,000015646108870
Train 10	20	0,000000005819716	0,000032759640399

From table 2 it is revealed out that the optimum network is a network with 9 hidden neurons (train 7) as it has the minimum final MSE and MAE. It has been also examined the MSE and MAE during training, validation and test procedure but the final are used in order to determine the network. It should be noted that there weren't significant variances.

3. Results and discussion

Implementing the whole process, through Matlab, some results are revealed. It has been created a graph for each algorithm where it is presented the tracked times and the predictions. For both of the two algorithms over than 1000 predictions have been executed. However, in the following figures it is presented a random sample of results.

It is obvious form the two graphs that the performance of ANN is much better than Kalman's Filter. This is easily noted from the table 3 where MAE and MSE are presented for each algorithm. The MSE of ANN is significantly minor.

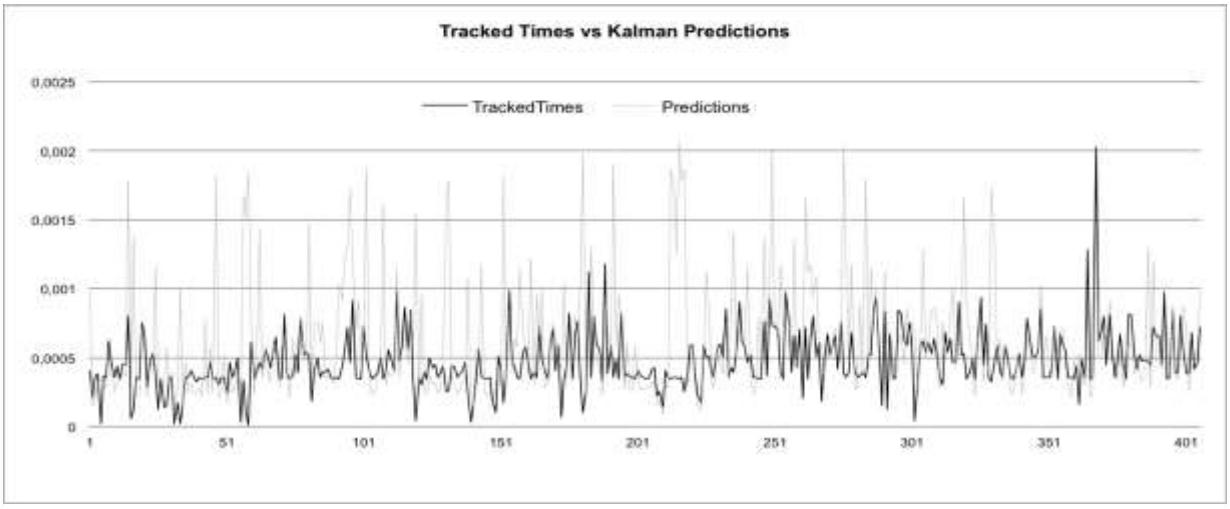

Figure 1: Tracked times and Predictions from Kalman Filter

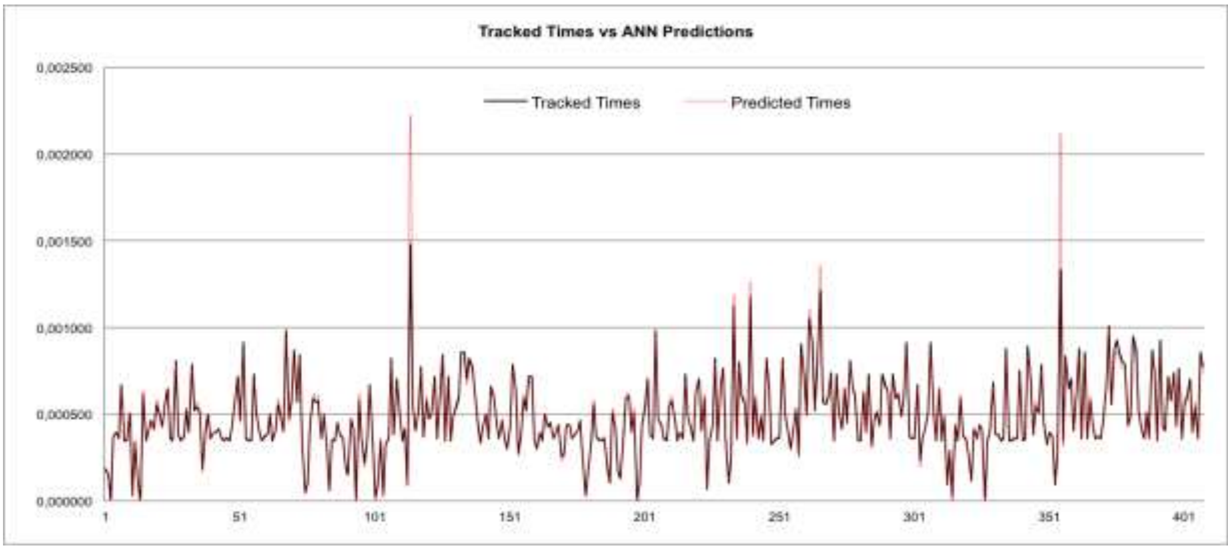

Figure 2: Tracked times and Predictions from ANN

Table 3: Comparative statistics for the two algorithms

	Kalman Filter	ANN
MAE	0,000277661506021	0,000000254151920
MSE	0,000000206635273	0,000000000038308

4. Conclusions

This system can affect positively and has already been applied in all the sectors of sustainable development. One of most significant application is to control the traffic especially at rush hour. The local Stakeholders based on the information provided from the traffic prediction system can initiate traffic control methods to avoid traffic jams. It is also a useful tool that indicates the vulnerabilities of the road networks. This system could also be used as a tool for urban planning aiming at a smart city defining the land uses according to traffic congestion spots. It helps also to increase the safety on the roads diminishing the number of accidents. Several approaches have been proposed for travel time estimation and prediction. The current study investigates the fle*et al*gorithm for the study-case of Thessaloniki based on previous studies of same authors concerning the GPS points classification. The basic requirements are computational, processing strength and a large amount of GPS points. So, it constitutes a cost-effective endeavor.

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