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# Web Application Service in Bus Arrival Time Prediction

***Abstract**. Bus arrival time prediction represents very important part of the service that informs passengers of intelligent transport systems in public bus transportation. Different methods are used for the prediction. In this paper, two methods for predicting arrival time of bus are analysed. Proposed method is the freely available Google's web service "DistanceMatrixAPI" . Comparative view of obtained results using the Kalman filter and Web service is presented. For the experimental research we proposed model of Distribution Modular Information and Communication System. Research results shows that the implementation of Kalman filter method is much more accurate that the use of "DistanceMatrix API" method.*

***Streszczenie.** W artykule zaprezentowano inteligentny system informujący pasażerów transportu publicznego o przewidywanym pczasie przyjazdu pojazdu. Analizowano dwie metody. NBajlepsze parametry miał system wykorzystujący filtr Kalmana.* ***Zastosowanie aplikacji sieciowej do prognozowania czasu przyjazdu autobusu w komunikacji miejskiej***

**Keywords:** Google API; web service; BATP; Kalman's filter
**Słowa kluczowe:** system prognozowania przyjazdu autobusu, filtr Kalmana.

## Introduction

Predicting the arrival time of buses BATP (Bus Arrival Time Prediction) in real time, is very topical but also at the same time very complex issue, which was in their research thoroughly dealt by Zaki, Ashour, Zorkany and Hesham [1]. Example of the service developed for the city of Chicago, and uses an algorithm to estimate the arrival time of buses, is developed by "Cleverdevices". In the area of Great Britain, a similar service was developed available on web-adresess (http://www.arrivabus.co.uk/timetables).

To predict the arrival time of buses a number of different mathematical methods were used [1]. Generally all methods can be divided into several groups [2,3]:

1.Historical approach - Includes methods that the estimation of the arrival time of bus base on median time required to cross the road section, based on data available for the same period of time in several previous days, which was dealt with in works of Raut, Goyal [4] and Altinkaya, Zontal [5].

2.Approach – in real time – Estimation of bus arrival time in next time period is equal to estimation of bus arrival time in present time period [8,9,10].

This approach means that the time of arrival has fluctuations within a certain narrow range, and does not take into account the unplanned interruptions in traffic, such as traffic jams, traffic accidents and other unforeseen circumstances.

3.Statistic model – Predicts time of arrival based on formed function of independent variables.

4.Approach based on model – Kalman filter outperforms all other developed models in terms of accuracy, demonstrating the dynamic ability to update on the basis of newly obtained data that reflect the changing characteristics of the environment. This algorithm is used to update the variable (time of travel) [4]

5.Machine learning techniques – Artificial Neural Network (ANN Artificial neural network) is one of the most widely used technique to evaluate traffic and its ability to solve complex nonlinear relations [2,3,4, 7,8].

## Materials and methods

Approach based on a model using Kalman filter provides excellent performance in terms of accuracy and updating of the results. Based on the methods that were researched (Reinhoudt, Velastin 1997), an algorithm was presented which predicted time required for bus to cross a particular section and is defined using the Kalman algorithm, Shalaby and others. [5,9,10]:

(1) $$g(k+1) = \frac{e(k) + VAR[data_{out}]}{VAR(data_{in}) + VAR[data_{out}] + e(k)}$$

$$a(k+1) = 1 - g(k+1)$$

(2) $$e(k+1) = VAR[data_{in}] \times g(k+1)$$

$$P(k+1) = a(k+1) \times art(k) + g(k+1) \times art(k+1)$$

where is: *g* gain of a filter, a gain of loop, *e* error of the filter, *P* prediction, *art(k)* duration of time that took the bus to cross the road section in the time of departure (k), *Art1(k+1)* duration of time that took the bus to cross the road section day before in the time of departure *(k+1), art2(k+1)* duration of time two days before in the time of departure *(k+1), art3(k+1)* duration of time three days before in the time of departure *(k+1).*

Input covariance *VAR[datain]* is calculated for the time of departure *(k+1)* using the actual driving times for the last three days *Art1(k+1), art2(k+1)* and *art3(k +1).*

(3) $$VAR(data_{in}) = VAR[art1(k+1), art2(k+1), art3(k+1)]$$

Covariance can be defined as general variable *X*, Chien, Ding Wei [6], Shalaby and others [5]:

(4) $$VAR[X] = E\left[\left(X - E[X]\right)^2\right]$$

For *E(X)* can be written:

(5) $$E(X) = avg(art) = \frac{art1(k+1) + art2(k+1) + art3(k+1)}{3}$$

Covariance can be calculated according to [5,6]:

$$\Delta_1 = [art1(k+1) - avg(art)]$$

(6) $$\Delta_2 = [art2(k+1) - avg(art)]$$

$$\Delta_3 = [art3(k+1) - avg(art)]$$

Finally VAR[datain] is equal [5,6]:

(7) $$VAR[data_{in}] = \frac{\Delta_1 + \Delta_2 + \Delta_3}{3}$$

Ideally for good characteristics of prediction it can be written [5]:

(8) $$VAR[local_{data}] = VAR[data_{in}] = VAR[data_{out}]$$

where VAR[localdata] presents newly introduced covariance and is equal to the covariance of input and output data. It can be written [5]:

(9) $$g(k+1)=\frac{e(k)+\mathrm{VAR}\left[\mathrm{local}_{\mathrm{data}}\right]}{e(k)+2\times\mathrm{VAR}\left[\mathrm{local}_{\mathrm{data}}\right]}$$

$$e(k+1)=\mathrm{VAR}\left[\mathrm{local}_{\mathrm{data}}\right]\times g(k+1)$$

Prediction of the arrival time of bus (n) on the bus stop (i+1) ATn(i+1) can be calculated using [5]:

(10) $$AT_{n(i+1)}=DT_{n(i)}+RT_{n(i,i+1)}$$

where are: *ATn(i+1)* evaluation of the arrival time of bus (n) on the bus stop *(i+1).* In our case one vehicle is used for the experiment so n=1. Number of bus stops used in the experiment is eight ($i_{max}$=8), *RTn(I,i+1)* represents predicted time from bus stop (i) to bus stop *(i+1), DTn(i)* represents the time of departure from the bus stop (i).

Prediction of arrival time *ATn(i+1)* uses parameter to evaluate the time of delay (n) on bus stop *(i+1)* and is based on the time of boarding/unboarding of passengers [5].

(11) $$DWT_{n(i+1)}=\lambda_{(i+1)}\times\left[AT_{n(i+1)}-AT_{n-1(i+1)}\right]\times\rho_{avg(i+1)}$$

where are: *DWTn(i+1)* is evaluation of time delay on the bus stop *(i+1), λ(i+1)* evaluation of time of passengers arrival to the bus stop given by Kalman predicting algorithm, *[ATn(i+1)-ATn-1(i+1)]* evaluation of progress of the bus *(n)* on bus stop, $\rho_{avg(i+1)}$ median time of boarding/unboarding of passengers (boarding passengers).

**Prediction of Arrival Time of Bus Using Web Service "DistanceMatrix API"**

Google's API „Distance Matrix" is a service that provides feedback on the distance between two points on the selected route and time of travel to a particular section, based on the request from user.

As input parameters, the initial and final destination which can be in the form of names or as geocoordinates of desired location are entered. Other parameters chosen are mode of transport, the unit in which the output value will be displayed.

For free-users of API there are limitations in the number of queries per day to 2.500/24h.

Response to the inquiry can be in two forms of documents, in XML and JSON (JavaScript Object Notation) format. Currently, the design of the proposed DMICS is supported by a rapid development of the applications that can be created using a variety of open source technologies such as HTML5, CSS (Cascading Style Sheet), JavaScript, PHP (Hypertext Preprocessor), Android, and GoogleMaps.

### The Design of the System Used in Experimental Research

The system that was used in the experiment consists of hardware components and software, which includes applications installed on the mobile phone placed in the transport vehicle, the applications installed on the tablet that is placed on the solar bus stop and multimedia web applications installed on the server.

The sensor module includes GPS / GPRS (Global Positioning System / General Pocket Radio Service) device (m smart phone based on Android OS), which is installed in the bus and is responsible for determining the geolocation of the bus in the experimental section of the road.

The obtained data of the geolocation of buses using the installed Android apps and GPRS technology are sent to the central server at the module responsible for the monitoring and managing of public bus services.

In order to detect geolocation of vehicles and sending data by GPRS technology to desired web page, is used publicly available application "Self Hosted", which is installed on a "smart phone".

This idea is based on the example of the use of "smart phones" as intelligent sensors, which is treated in the paper [11] with the aim of monitoring the degree of occupancy of the bus. Modular architecture DMICS's (Distribution Modular Information and Communication System) is shown graphically in Fig. 1.

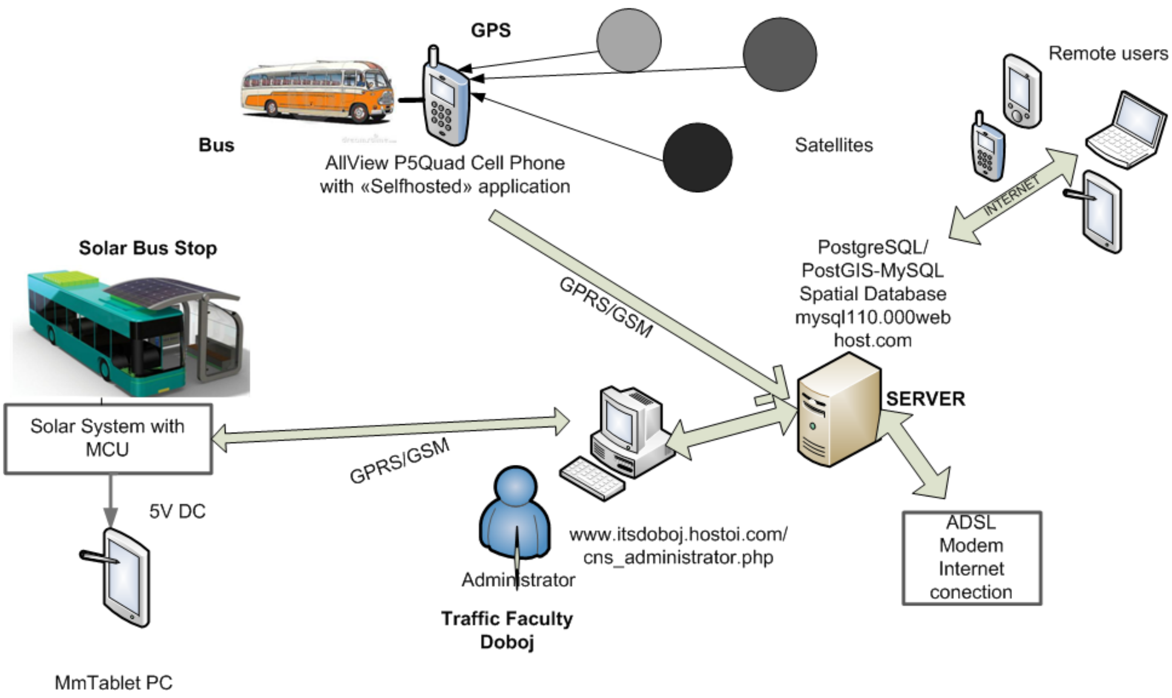


Fig. 1. DMICS architecture

## Results and Discusion

Estimation of arrival time (using web service "Distance MatrixAPI) of bus to bus stop is made without including time spent on bus stop (boarding/uboarding of passengers, bus delay), and presents the time it takes for bus to cross the section from start A to destination B.

Fig. 2 shows block diagram with the spacing between bus stops and the estimated times of arrival of the bus at the designated bus stop.

The system was tested on a section of road Doboj-Prnjavor. For the estimation of arrival time of buses at selected positions two methods were used:

1) The method using web service "Disatnce MatriX API"

2) The method using Kalman filters to predict the arrival time.

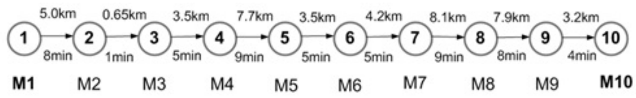


Fig. 2. Block scheme of road section with mutual distances

For comparison between methods, one segment-section between measuring points M6 and M7 was chosen. Calculated data for this section of road using method with Web service is shown in Table 1.

Table 1. Estimation of arrival time using web service

| Road section | Distance | P1 | P2 | P3 | P4 | P5 | M |
|---|---|---|---|---|---|---|---|
| M6-M7 | 4.2km | 4m 10s | 5m | 5m 50s | 4m 20s | 5m 20s | 5m |

Legend: P1-P5: Estimated arrival time, M- measured time.

By measuring, average delay times of buses for each bus stop are determined individually. Median average value of time of delay on bus stops is calculated as median arithmetic value of all measured bus stops:

$$\bar{x} = \frac{\sum_{i}^{n} x_i}{n} = \frac{\sum_i^9 x_i}{9} = \frac{450}{9} = 50\,\sec. \tag{12}$$

Total time of one transport cycle on relation M1-M10 is: 54min+7.5min=61.5min.

Table 2. Estimation of arrival time using Kalman filter

| Bus Start Time | art3 | art2 | art1 | Avg. | Δ3 | Δ2 | Δ1 | VAR [loca] | g(k+1) | a(k+1) | e(k+1) | P(k+1) | Ms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11:19 | 6m 45s | 6m 20s | 5m 45s | 6m 16s | 13m 20s | 11s | 16m 45s | 10m 5s | 0,51 | 0,49 | 5m 9s | 5m 52s | 6m 5s |
| 14:19 | 5m 20s | 6m 10s | 5m 55s | 5m 48s | 13m 4s | 8m 4s | 49s | 7m 19s | 0,63 | 0,37 | 4m 36s | 5m 58s | 6m |

Estimation of arrival time (using the Kalman filter) of buses was made on the basis of patterns provided in chapter 2.

Table 2. presents the calculated time of arrival for a selected section between measured points M6 and M7.

It is evident from the results of obtained prediction *P(k + 1)* and the measured results (*Ms*) that there is some error (ε) in prediction of Kalman filter. On the basis of the following form median relative error $\varepsilon_{avg}$ can be calculated:

$$\varepsilon_{avg} = \frac{1}{N}\sum_{t}\left|\frac{X_t(t) - X_e(t)}{X_t(t)}\right| \tag{13}$$

where are: $X_t(t)$ – accurate value obtained by measuring, $X_e(t)$- estimated value, *N*- number of measurements.

Prior to drawing any conclusions about passenger traffic intensity and dwell time at bus stops, we processed the collected data and conducted an analysis of the data stored in the database which contains the information on bus arrival times and bus locations.

The estimation of the bus arrival time at a desired bus stop was made on the basis of the dwell time and the passenger service time; therefore, the obtained data represent the total trip time.

For the experimental research we used 50 measuring which are put in the database. Based on the analysis of the experimental data obtained from this research, we designed a platform for the optimization of the bus schedule and the total trip time on the observed section of the road.

Comparison of results of obtained median error $\varepsilon_{avg}$ for selected section is shown in Table 3.

Table 3. Estimation of arrival time using Kalman filter

| | |
|---|---|
| „Distance Matrix API“ $\varepsilon_{avg}$ | 0,106 |
| Kalman's Filter $\varepsilon_{avg}$ | 0,0211 |

The results show that the method of predicting the arrival time of the bus at the bus stop with the Kalman filter provides results with smaller average error than the method with web service.

## Conclusion

The paper discusses two methods used in the intelligent transport systems of public bus transport, in order to accurately predict exact time of arrival of buses to bus stops. The analysis of the total trip time on a selected road section was carried out with respect to the results of experimental measurements of the quality parameters of the data sampled from the transport infrastructure, as well as the results of the estimation method based on the usage of an web technology, intelligent transportation system, and DMICS for monitoring and managing public bus transport.

The results point much higher prediction accuracy using the Kalman filter, with median relative error $\varepsilon_{avg}$=0.0211, but on the other hand method that uses Google's services has a number of advantages because it shows how to use Web services as a method of predicting the arrival time of buses to bus stops. It must be noted that Google's service is not strictly intended for the implementation of this kind and therefore is not expected of having a high level of accuracy in prediction.

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