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Hardware-software complex of informing passengers of forecasted route transport arrival at stop

V Yu Pogrebnoy[1], M I Pushkarev[1], A S Fadeev[1]

[1]Tomsk Polytechnic University, 30, Lenina Ave., Tomsk, 634050, Russia

E-mail: pogrebnoyvadim@tpu.ru

Abstract. The paper presents the hardware-software complex of informing the passengers of the forecasted route transport arrival. A client-server architecture of the forecasting information system is represented and an electronic information board prototype is described. The scheme of information transfer and processing, starting with receiving navigating telemetric data from a transport vehicle and up to the time of passenger public transport arrival at the stop, as well as representation of the information on the electronic board is illustrated and described. Methods and algorithms of determination of the transport vehicle current location in the city route network are considered in detail. The description of the proposed forecasting model of transport vehicle arrival time at the stop is given. The obtained result is applied in Tomsk for forecasting and displaying the arrival time information at the stops.

1. Introduction

The rapid development of new technologies makes them an essential element of different fields of activity of modern society beginning from the primary education and ending with the investigation and solution of complex problems in different fields of science.

Thus, for instance, as of today, the first light-emitting diode, proposed in the 1960-s and emitting only incandescence, has a vast colour spectrum and is applied in high-brightness searchlights, car headlamps, flexible self-adhesive ribbons and domestic and industrial lamps.

A separate class of devices is the systems of visualization of the text and graphic information based on light-emitting diode matrices. One of the most widely-spread devices realised on the basis of light-emitting diodes is light-emitting diode information boards. Light-emitting diode boards have found their application in many branches of human life activity:

– advertising light-emitting boards and screens;
– a transport branch: visualization of the transport timetable and electronic boards of arrival;
– a banking sector: rates of exchange and shares;
– establishment of the service sector: display of the information and warnings sent by the Russian Ministry for Emergency Situations, the composition and pollution of the air, the levels of the background radiation, different information on an institute (reception hours of specialists, service cost, news, informers of electronic queues), the information from administrative authorities, dates and times;
– industrial enterprises (notification of the operating personnel).

Thus, light-emitting diode boards are the modern tool of notification of the population and visualisation of information, which can be used in different fields and spheres of human life activity.

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In this paper, the application of the light-emitting diode information board at the stops of the public transport, which represents a client side of the automated distributed interactive system intended for informing passengers of the time of passenger public transport arrival at the stop, is considered.

2. Materials and methods

The hardware-software complex of informing the passengers of the passenger traffic consists of:

1) a server side including databases and three basic modules: a module of recording the statistics of traffic, a module of intelligent forecasting and a module of interaction with clients;
2) a client side representing light-emitting diode boards installed at the passenger transport stops or mobile and web-based applications.

The database of the informational system stores the history of movement of transport vehicles (TV), the statistics of transport passage of checkpoints, updated and historical data on the intervals of movement between the checkpoints and on the temporal delays at checkpoints. Storage of the updated data allows representing the current situation on roads, and the storage of historical data — the average statistical information on the traffic in different sections in different periods of time.

The structure of the information system is presented in fig. 1

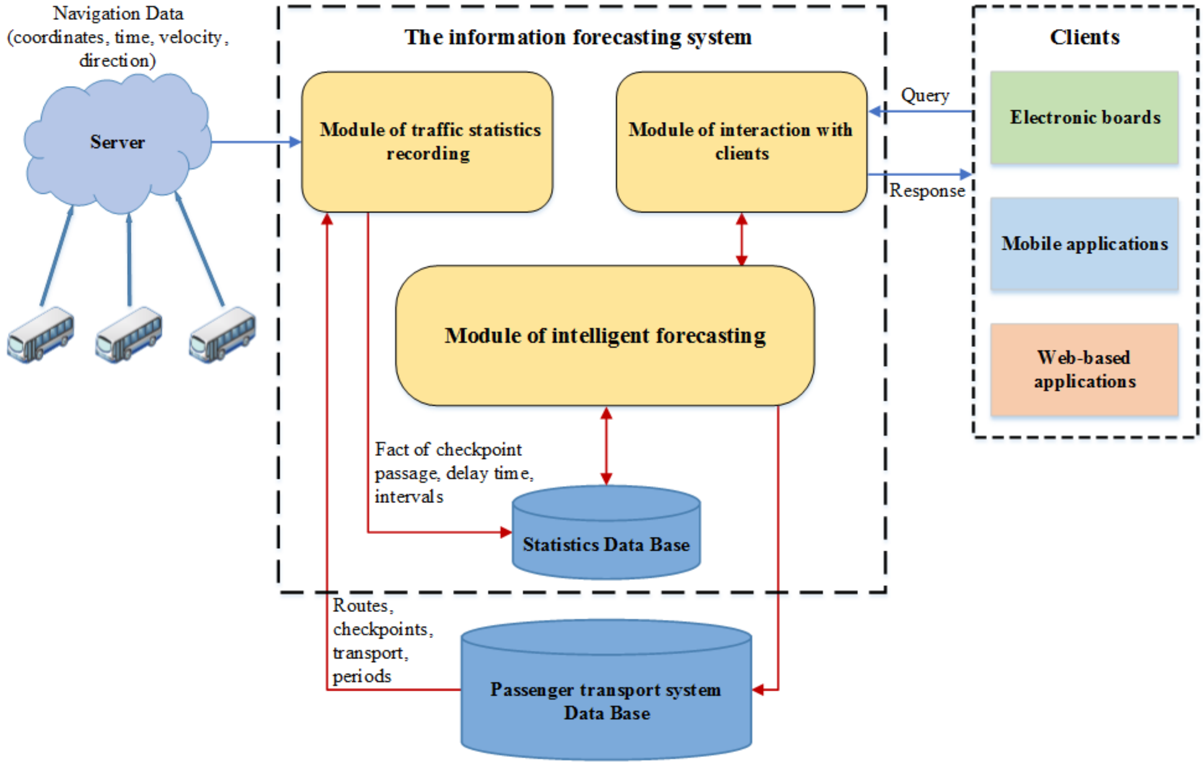

Figure 1. The structure of the forecasting system

The module of recording the traffic statistics performs the function of downloading updated and historical data, obtained with the use of the algorithm of traffic parameters recording, to the databases. At regular intervals, the module receives the latest navigating telemetric data (NTD) of TV and performs the algorithm of recording cyclically. The operational algorithm of this module controls the finite automate of determination of directions in the route, constantly changing TV states in the system. The module records the moments of checkpoints passage by the transport, carries out calculations of updated and average intervals of traffic, as well as updated and average delay periods at checkpoints.

The module of interaction with clients expects the queries from the informers and other systems, receives the necessary data from the module of intelligent forecasting and provides them according to

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a certain protocol in the required format to the requesting object.

The module of intelligent forecasting analyses the information, stored in the database, in order to forecast the traffic parameters. In the system, the algorithm of forecasting of the time of transport arrival at the object of control by different routes is applied.

3. The model and the algorithm of forecasting

To forecast the time of the transport arrival at the stops, a model based on the historical data has been developed. The model takes into consideration both average values of the parameters of the traffic in separate sections of the route and the latest parameters of the traffic observed on a real-time basis in the same sections of the route. At the same time, the influence of the average values of the parameters has a direct dependence on the TV remoteness from the stop for which it is necessary to forecast the arrival time, and the influence of the latest values has an inverse dependence. Additional storage of the updated values of traffic parameters allows considering the real traffic situation. The algorithm of this model is carried out within the module of intelligent forecasting on a real time basis using the statistics which is accumulated by the module of recording traffic statistics.

A light-emitting diode information board is connected to a information telematic server of the forecasting system of the motor transport enterprise with the use of the Internet. The access to the Internet is realised through the network of cellular communication operators with the use of GSM-protocols. The informational telematic server forms the final information, displayed on the light-emitting diode board, and controls the board operation remotely.

4. The client side

On the basis of the review of the existing analogues of light-emitting diode matrix indicators, a number of drawbacks have been revealed:

1. low reliability of the systems using the built-in computers with operating systems inappropriate for the functioning on a real time basis (Linux);
2. high requirements for the computational capabilities of the systems developed on the basis of the high-level languages, such as Python and C#;
3. substantially bounded functional of devices using standard video processors for advertising light-emitting diode boards;
4. limited temperature conditions and climate designs of the ready-made devices;
5. the necessity of connecting to the Internet and others.

In connection with this, the hardware component of the information board and its control were realised by means of the controller ‘Atmega 328p’, for which the original software was developed. The developed software (SW) provides the realisation of the following functions:

– installation of the TCP-session intended for the information exchange with the information telematic server;
– formation of queries in accord with the unique protocol to the server of the forecast service;
– decoding of the information, obtained from the server, and formation of virtual pages of the text on its basis;
– alternate displaying of the virtual pages of the text on the light-emitting diode matrix;
– calculation of the arrival time of each tram, trolleybus and bus on the basis of the values of the current time and the information received from the server of the forecast system;
– exclusion of the strings from the readout for those transport vehicles that have already arrived at the current stop.

The original software for the microcontroller ‘Atmega 328p’, installed in the board, possesses a number of functional peculiarities:

– updated information output about the numbers of routes, destinations and the time of the transport arrival with an opportunity of static displaying of the part of the text at the beginning (a number of the route) and at the end of the string (the time before arrival) and an opportunity of horizontal scrolling of the part of the text in the centre of the string (the name of the last stop);

– information output in the page mode with alternation of all routes, the data of which have been received from the server; automatic formation of pages from the number of strings being in the memory;
– automatic reduction of the value of the time remained before the arrival of a bus, a trolleybus, a tram of each route in the absence of the correcting information from the server;
– automatic exclusion of the displaying of the string, the time value of which has reduced to zero, from the memory and from pages;
– the output of the information on the current time and the temperature in the place of the board installation;
– an opportunity of the use of the entire information field of the board for displaying the coherent text formed on the server side or the creeping lines by the instruction of the server for the possibility to display updated and advertising information;
– an opportunity of changing the speed of scrolling the creeping lines, the speed of changing the information pages, the brightness of diode light emission;
– displaying of the preprogrammed text information in the absence of the opportunity to setup a connection with the server during a certain time interval.

5. The server side

In the sphere of passenger transportation, the application of the systems of automatic locate of TV has become widespread, in particular, of global navigation satellite systems (GLONASS and GPS) [1, 2]. Owing to the use of these systems, there is an opportunity to trace the location of TV in real time and to forecast their further movement, which is a base element of intelligent transport systems (ITS) [3, 4]. The application of NTD, the information on the route combined with intelligent algorithms allows the most accurate forecast of the passage transport arrival time at the required point [3, 5].

The majority of the existing models of forecasting use GPS-statistics, which represents the history of the parameters of TV movement, obtained by the method of the periodic survey of TV, as initial data. These data are interpreted differently in each of the models and are transformed into the input parameters of this model. The output parameters of the model are the forecast times of TV arrival at subsequent route stops [6-11].

6. Designing the forecasting system

The task of the system is to forecast the time of TV arrival at the stop with the use of intelligent models and algorithms of forecasting.

The objects of control of the forecast system are passenger TV: trolleybuses, trams, and buses. The majority of units of the rolling stock of the passenger transport is equipped with navigating-communication equipment GLONASS or GLONASS/GPS, providing determination of the current location and parameters of TV motion.

NTD, obtained with the use of the global navigating systems, do not depend on the network of streets, contain errors, and there is no unique method of coordinates approximation and recording of the parameters of TV motion [3]. A new method of location record and accumulating of the statistics of values of TV motion parameters is proposed. For this purpose, the stops coordinates, the radius or ground, occupied by them, are integrated into the unified system, which allows determining the moment of TV arrival at the stop and the instant of its departure from it. The formed structures of the route in the form of sequence of its stops provide the tracing of the TV movement according to the plan of a specific route.

Let us determine the sought location uniquely by route section s_j with order number *j*, connecting p_j and p_{j+1} nodes and with distance λ, covered from the beginning of the section. Let us consider three cases of coordinates' location V relatively the perpendiculars drawn through the nodes having coordinates O_j^p (Figure 2a).

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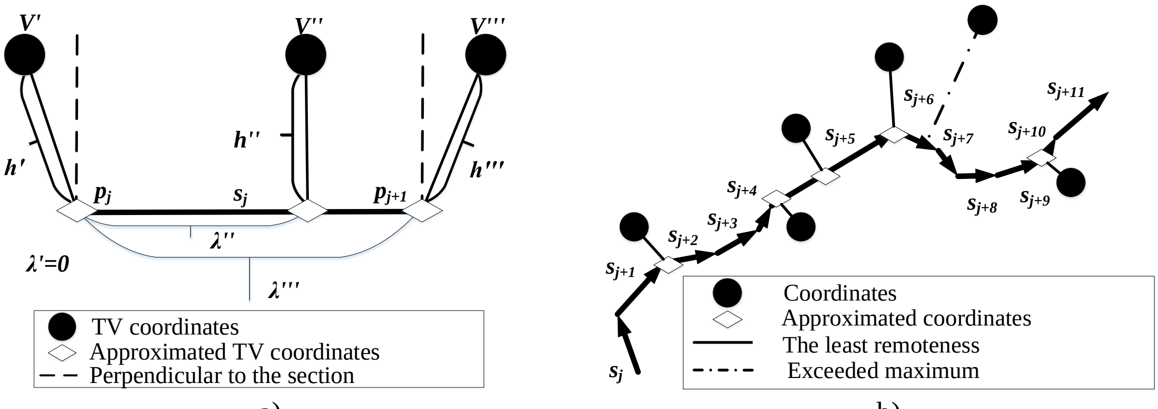
Let us call the calculation of λ according to formulae 1 and 2 as approximation of the V point by section s_j:

$$h = \begin{cases} \left|\overrightarrow{O_j^p V}\right|, & \left(\overrightarrow{O_j^p O_{j+1}^p}, \overrightarrow{O_j^p V}\right) \le 0 \\ \left|\overrightarrow{O_{j+1}^p V}\right|, & \left(\overrightarrow{O_{j+1}^p O_j^p}, \overrightarrow{O_{j+1}^p V}\right) \le 0 \\ \dfrac{\left|\left[\overrightarrow{O_j^p O_{j+1}^p}, \overrightarrow{O_j^p V}\right]\right|}{\left|\overrightarrow{O_j^p V}\right|}, & \text{otherwise} \end{cases}, \tag{1}$$

$$\lambda = \begin{cases} 0, & \left(\overrightarrow{O_j^p O_{j+1}^p}, \overrightarrow{O_j^p V}\right) \le 0 \\ \left|\overrightarrow{O_j^p O_{j+1}^p}\right|, & \left(\overrightarrow{O_{j+1}^p O_j^p}, \overrightarrow{O_{j+1}^p V}\right) \le 0 \\ \sqrt{\left|\overrightarrow{O_j^p V}\right|^2 - h^2}, & \text{otherwise} \end{cases}, \tag{2}$$

where h – remoteness of TV from the section.

Let us determine maximum possible remoteness of TV from route $\tilde{h}$ and function $f_n{:}\left(S,V\right) \mapsto \left(s_\zeta, \lambda\right)$, approximating coordinates V by section $s_\zeta = \underset{s_j \in S}{\arg\min}\left(h\right)$, at that $h > \tilde{h} \Rightarrow \nexists s_\zeta$. Let us call function f_n as approximation of point V by the multitude of sections S. Figure 2b presents a graphic interpretation of approximation of several points by a piecewise-linear diagram presenting some multitude of sections S.



a) b)

Figure 2. Determination of TV location: a – in the section; b – on the route

For determination of multitude S and, correspondingly, for solution of the set problem, a method based on the finite-state machine has been developed [3]. TV can be in ten states: q_0 – location is unknown; q_1 – the route is determined; q_2 – the direction of the route is determined; q_3 – TV turned out to be in the initial node of the section; q_4 – TV turned out to be between the initial and final node; q_5 – TV turned out to be in the final node; q_6 – TV arrived at the initial node; q_7 – TV departed from the initial node; q_8 – TV arrived at the final node; q_9 – TV completed the route.

Transition $q_i \to q_0$ means the absence of NTD or leaving the route. Transitions $q_{i=\overline{3,8}} \to q_{j=\overline{3,5}}$, named as skips, appear in case of passage of nodes and sections. In figure 3, there is a scheme of the finite-state machine without taking into consideration unexpected situations and skips.

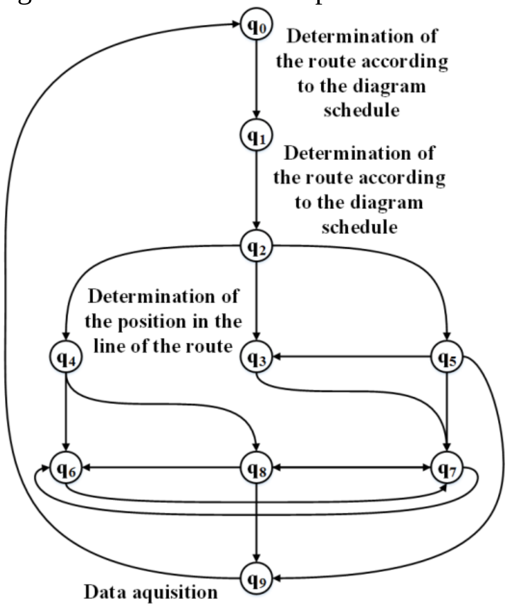


Figure 3. The scheme of the finite-state machine

Transition $q_0 \to q_1$ appears after determination of the route according to the current TV timetable. For transition $q_1 \to q_2$, the method, based on the tracks of TV movement, is constructed in each direction of the route, and based on the choice of the optimum track by the length and a minimal departure from the TV schedule.

7. Parameters recording

Let us determine the moment of the state change as t^{qi}. The interval of movement along the section is calculated during transition $q_7 \to q_8$: $i = t^{q8} - t^{q7}$. The delay time in the node is calculated during transitions $q_6 \to q_7$, $q_8 \to q_7$: $dt = t^{q7} - t^{q6,q8}$.

For determining $t^{q6,q8}$ and t^{q7}, it is necessary to define the location of TV: within the node or outside it. If the node is represented by a circumference with radius ρ, the fulfilment of inequality $\left(x^V - x^O\right)^2 + \left(y^V - y^O\right)^2 \le \rho^2$ is checked; if by a polygon, the method of ray tracing is applied.

Values i and dt are random only in the context of certain conditions: the type and the technical state of TV, the route, the driver's behaviour, the road condition, weather conditions, etc. To decrease the number of criteria limiting the randomness of the specified values, let us distribute the values throughout the sections and nodes of the routes, as well as by the seasons of the year, by weeks and hours.

The obtained random values have normal distribution [4], and there is a possibility of calculation of their statistic parameters:

$$\mathrm{M}_{\eta+1}\left[Z^m\right] = \frac{\eta * \mathrm{M}_{\eta}\left[Z^m\right] + Z^m_{\eta+1}}{\eta+1}, \tag{3}$$

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where Z^m – the random magnitude value of period *m*; η – the number of the obtained earlier values of random magnitude value Z^m; $\mathrm{M}_\eta\left[Z^m\right]$ – mathematical expectation of magnitude Z^m by η values; Z^m_η – the η-th value of random magnitude value Z^m

$$\mathrm{D}_{\eta+1}\left[Z^m\right]=\frac{\eta}{\eta+1}\left(\mathrm{D}_\eta\left[Z^m\right]+\frac{\left(\mathrm{M}_\eta\left[Z^m\right]-Z^m_{\eta+1}\right)^2}{\eta+1}\right), \tag{4}$$

where $\mathrm{D}_\eta\left[Z^m\right]$ - the variance of random magnitude value Z^m by η values.

8. Conclusion

On the basis of the problem analysis of the passenger transportation system functioning in Tomsk city, new model and algorithmic solutions of forecasting the transport vehicle time arrival at the stop are proposed in the article. Original methods and algorithms of the transport vehicle current location determination in the city route network, methods of statistics accumulation of transport vehicle traffic parameters on the basis of navigating telemetric data, obtained from global navigation satellite systems (GLONASS and GPS), are considered in detail. The prototype of the electronic information board for public transport stops that allows displaying forecasting data of arrival time of the transport vehicle is proposed. The protocol of interconnection of the forecasting server with electronic information board is represented. Obtained results have been successfully adapted to the intelligent route network of Tomsk city. Electronic information boards, displaying the arrival time of the forecasted transport vehicle on the basis of described methods and algorithms, are set and operate at the public transport stops.

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