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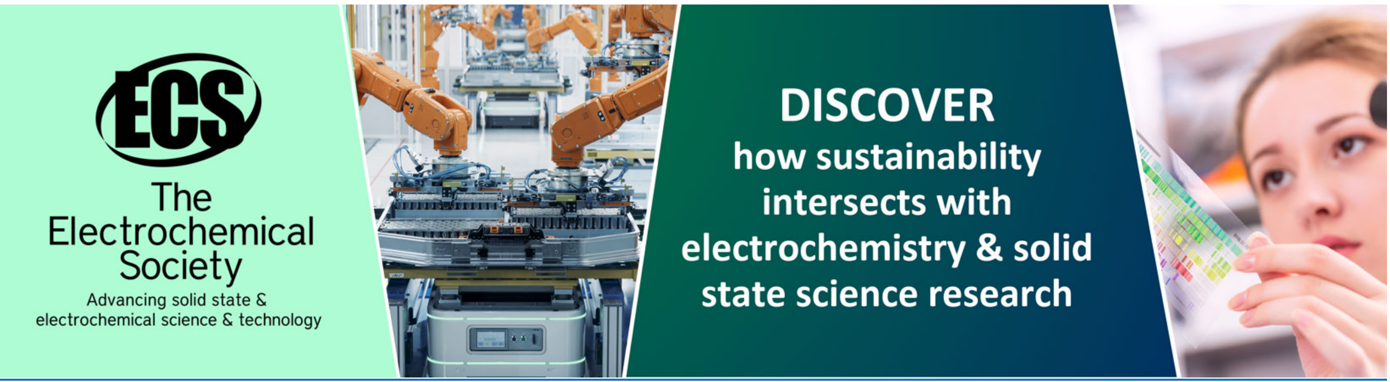

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The task of determining the actual routes in the traffic control system using satellite navigation

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Abstract. The paper deals with the task of determining the actual traffic routes based on the data of the global satellite navigation system during the dispatching control of road transport. The actual route through the transport network is an ordered set of traffic control points passed. The fixation of control points of the route in the processing of satellite navigation data is carried out by means of two radii: the radius of detection and the radius of positioning. The paper proposes a method for processing satellite navigation data, consisting of two stages: first, pre-processing and, second, calculating the parameters of the system states defined by the dispatch control tasks. The state of the system controlled by the traffic dispatcher system is described.

1. Introduction

Currently, passenger dispatch control systems play a crucial role in ensuring the reliability and safety of the road transport system, and meeting the needs of the population in transport services. Information systems of transport dispatching control are based on the latest achievements of science in computer technology, mobile communications and satellite global positioning systems. Today, information dispatch systems are used in passenger public transport, freight traffic, as well as special transport: school transportation, ambulances, emergency services, etc. [1-5].

The data recorded in the dispatching system should provide: control of driving speeds, drivers' work and rest schedules, compliance with actual and planned transport work.

Thus, one of the main tasks of the information dispatching system is the provision of real-time information about events requiring attention and quick response. The parameters of the states of the controlled system must be recorded, which allow to determine in real time the following data: the ratio of actual and planned processes to their unacceptable mismatch; deviation of the actual processes from the specified limit values.

2. The solution of the problem

Currently, the discrete event method [6, 7] is widely used to describe the systems under consideration, according to which the functioning of the system is described as a chronological sequence of events. The event occurs at a certain point in time and causes a change in the state of the system.

In modern systems of traffic dispatching control, the satellite navigation system (Global Navigation Satellite System) is used to control the movement of rolling stock, which provides vehicle positioning. Determining the ratio between the planned and the actual movement of rolling stock is carried out through control points located on the transport network. When performing regular transportation checkpoints are stopping points of the route, bus stations and bus stations. In addition, there may be technical checkpoints on the route, intended for fixing crew change points, crew rest, meals for passengers, etc. For irregular transportations (cargo, special, custom, etc.) the corresponding set of control points is determined, which provides the tasks of dispatching traffic control.

In graph theory [8], a transport network is a directed graph $\boldsymbol{G} = (\boldsymbol{W}, \boldsymbol{E})$ in which certain properties can be specified for an edge $(u,w) \in \boldsymbol{E}$, for example, restrictions on permissible motion speed $v(u,w) <= v_{\max}$. Each vertex $w \in \boldsymbol{W}$ has coordinates (latitude and longitude) that ensure the positioning of the vehicle on the ground through signals from the satellite navigation terminal.

A route $\boldsymbol{M}$ on a graph $\boldsymbol{G}$ is a sequence of vertices $w_1,\ldots,w_i,w_{i+1},\ldots,w_t$, where a pair of neighbouring vertices w_i, w_{i+1} is an edge of the graph.

Let us consider the task of fixing the actual movement of the vehicle along the route by means of satellite navigation. The data of the satellite navigation system come to the control room at intervals τ. The vehicle's fixation of the control point is carried out by finding the coordinates in its zone, which is usually specified by the radius. The radius of the control point must be large enough to compensate for possible errors in its coordinates, errors in the satellite positioning system, as well as the technological features of the stopping point, which may have several places for transport stops.

In some control points of the route, the vehicle may not be stopped. These are, for example, control points that determine the beginning or end of a particular section of the route (with speed limits, etc.). When determining the positioning radius for such points, the vehicle speed and the time intervals between satellite navigation data packets should be considered. The histogram of the distribution of intervals between the packages of the satellite navigation system is shown in figure 1. The information was obtained as a result of processing of 332 thousand packets of real dispatcher control data. The figure shows that 99% of packets have an interval of less than 40 seconds, because to fix a control point it is enough if there is one dimension in it, i.e. at a speed of 90 km/h, the radius of the control point must be at least 600 m.

A large radius value results in a false fix of the control point. Figure 2 shows the scheme of fixing control points of the transport network. The figure shows that the control point can be fixed in the route, although it is not in the path of the vehicle. To avoid false fixation, it is proposed to use two radii when processing satellite navigation packages: the radius of detection ($r_i^{'}$) and the positioning radius (r_i). A larger detection radius is used to fix the vehicle in the reference point area. The positioning radius is intended to determine the event of the route passing through the control point: it is considered that the vehicle has passed through the control point if its trajectory passes through the zone of positioning radius.

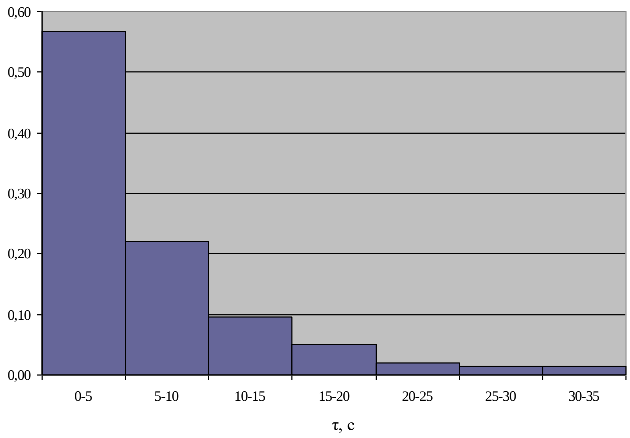

Figure 1. Histogram of the distribution of time intervals between satellite navigation system data packets.

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This paper proposes the following procedure for processing satellite navigation data entering the dispatch control system of motor vehicles: preliminary processing; calculation of parameters of system states defined by dispatch control tasks.

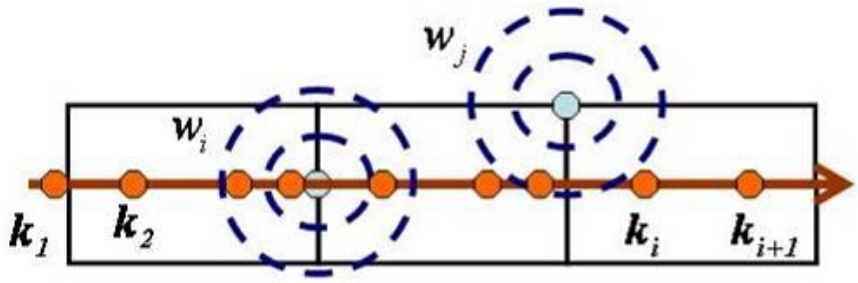

Figure 2. Illustration of fixation of the transport network in the route of the control point: $k_1, k_2, ..., k_i$ - data packages of the satellite navigation system.

At the pre-processing stage, a relational ratio of marks (tracks) of satellite vehicle positioning is formed: $\boldsymbol{P(A, T, \Phi, \Lambda, T^{'}, L^{'}, V, I, L)}$ having the following attributes:

- $\boldsymbol{A}$ - vehicle identifier;
- $\boldsymbol{T}$ - time positioning;
- $\boldsymbol{\Phi, \Lambda}$ - coordinates (latitude and longitude) of the location of the vehicle;
- $\boldsymbol{T^{'}}$ - link to the previous mark;
- $\boldsymbol{L^{'}}$ - distance to the previous mark;
- $\boldsymbol{V}$ - vehicle speed;
- $\boldsymbol{I, L}$ - the identifier of the nearest control point of the transport network in the zone where the mark is located, and the distance to this point.

Preliminary processing of satellite positioning data is carried out by a special application server (navigation track processing server).

At the next processing stage (the stage of calculating the system state parameters defined by dispatch control tasks), a set of dispatch control states is formed on the basis of a set of navigation marks - a relational relationship $\boldsymbol{S(A, K, I^{'}, Z, I, L, \Phi, \Lambda, T^{b}, T^{e}}$ with attributes:

- $\boldsymbol{K}$ - mark number;
- $\boldsymbol{I^{'}}$ - state identifier of the managed object;
- $\boldsymbol{Z}$ - a parameter having values depending on the state identifier;
- $\boldsymbol{T^{b}, T^{e}}$ - time points of the transition of the managed object to the state and exit from this state.

The set of managed object states $\boldsymbol{S}$ is generated by the system state processing server.

The following states of the managed object are defined for dispatch control a:

- Exceeding the permissible speed of movement (subset $\boldsymbol{S^{v}} \in \boldsymbol{S}$);
- Vehicle stops ($\boldsymbol{S^{t}} \in \boldsymbol{S}$);
- Location of the vehicle in the detection zone of the control point of the transport network ($\boldsymbol{S^{r}} \in \boldsymbol{S}$).

The ordered set of checkpoint positioning states $\boldsymbol{S^p}$ is the actual motion path on the transport network. To control the completed transport work, it is necessary to assess the compliance of the planned and actual processes of rolling stock movement.

The planned route is described by a relational ratio $\boldsymbol{R(K,T^b,I,T^e)}$ with the following attributes:

- $\boldsymbol{K}$ - the number of the route point;
- $\boldsymbol{T^b}$ - time of arrival at the control point;
- $\boldsymbol{I}$ - checkpoint identifier;
- $\boldsymbol{T^e}$ - departure time from the control point.

Thus, for the planned route $\boldsymbol{R_j}$ it is necessary to match the actual route $\boldsymbol{S_j^p}$. It should be noted that not all elements corresponding to the planned route may be present in the actual route $\boldsymbol{S_j^p}$. There may be elements in the actual route that are missing from the planned route $\boldsymbol{R_j}$.

This problem is solved as follows:

1. Using the maximum likelihood method [for example, 9], the starting and ending points corresponding to the planned route are determined in the actual path of the vehicle.
2. A general sequence of two ordered sets is formed: points of the planned and actual routes of movement. For this purpose, the algorithm of the classical dynamic programming problem of finding the largest common subsequence (LCS) of several lines was used [10].

3. Analysis of the results

The navigation data processing method described in this paper is implemented in the dispatch control subsystem of the BusTrafficManagement information system, which is used to organize and manage passenger traffic along bus routes in Krasnoyarsk Region. The operator of this system is OJSC “Avtokolonna 1967” (Krasnoyarsk) - one of the largest passenger carriers in the Siberian region. The implementation of the dispatching system on regular and special bus transportation allowed us to ensure:

- Regularity and the corresponding level of quality of traffic due to tight control of the timetable;
- Transportation safety due to real-time monitoring of the permissible parameters of the transport process: speed limits, crew operating modes, etc ;
- Operational control and comprehensive analysis of the status of bus trips, automatic identification of "problem" flights for analyzing the situation and making decisions of the dispatch control;
- Analysis of the executed schedule for a specified period of time, allowing to identify problem areas of the route and optimize the schedule.

4. Conclusion

The article proposes a new approach to determining the state parameters of the controlled system in real time, which provide dispatcher control of the actual process deviations from the specified limit values, as well as the ratio of actual and planned parameters in order to detect unacceptable inconsistencies that require corrective decisions.

For the description of the transportation process in the system of dispatching control of road transport, the discrete event method was used.

The paper proposes a method for processing satellite navigation data, which consists of two stages: first, pre-processing and, second, calculating the system state parameters for dispatch control tasks.

The state of the system, controlled by the dispatching control of traffic in road transport, has been determined. The proposed methodology has been tested in the dispatch control subsystem of bus traffic information system BusTrafficManagement. Experience of practical implementation allows us to conclude that the technique has a good performance, which allows it to be effectively used in practice in the systems of dispatching control of road transport.

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