The development of basic algorithms for processing navigation data in dispatching control systems of road transportation of goods and passengers

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Abstract. The development of basic algorithms for processing navigational data in dispatching control systems of road transportation of goods and passengers on specified routes is discussed in this article. Algorithms for processing navigation data with the use of GIS-technologies are described. The features of the "linking" of navigation marks to the zones of control points represented in the spatial model of the route by polygons formed by means of specialized editors of geographic information systems are described. The algorithm of recognition of flights performed on a given route based on the analysis of the actual data on the passage of checkpoints of the route by the vehicle, as well as the algorithm of recognition of liberty mileage is considered in detail. The description of the algorithm for comparing the planned and actual indicators of transport work developed using the theory of sets is presented. A block diagram of an algorithm for a step-by-step evaluation of the results of performing transport work is presented on the basis of the application of the procedure of stepwise narrowing of the set of admissible alternatives.

1. Introduction

The main feature of the navigation control of vehicles performing transportation of goods or passengers on specified routes is the use of specialized spatial models of objects on the route, called virtual checkpoints.

If you define the real objects of the planned tasks in the form of an ordered sequence of virtual checkpoints (CKPT), located on the route, such checkpoints can be represented as a set of so-called geometric primitives, which are polygons. This approach to the formation of CKPT is to apply a polygon on an electronic geographical map of the area where the object of interest is located. At receipt in dispatching system of each navigation mark from the controlled vehicle the fact of its occurrence in each of the polygons representing checkpoints is checked. The process of determining the CKPT, which belongs to the navigation mark (NM), is "linking" NM to the CKPT. It is assumed that polygons cannot intersect, so any geographic point (x; y) in area G cannot belong to two or more polygons at the same time. In practice, this restriction is used to simplify subsequent information processing algorithms. If it is necessary to change the type of zones, this change is reduced to a dynamic indication of the type of checkpoint for a particular job [1, 2].

In the considered system, the described algorithm is based on the search for intersections of the coordinates of NM with the boundaries of CKPT. CKPT consist of primitives: triangle, rectangle or
circle. If the CKPT contains more than one primitive, this CKPT is called a complex checkpoint (CCKPT), and if CKPT consists of one primitive, it is called a simple checkpoint (SCKPT). If it is not specified how many primitives a CKPT consists of, such a CKPT should be referred to a complex checkpoint [3].

The zone of the complex control point is the area of imposing at least one of the primitives of which the CCKPT consists. The result of "linking" the NM to a specific CKPT is the Boolean number. Previously, it was noted that the checkpoint zones cannot overlap each other, so they cannot be "not linking" to any CKPT or "linking" to only one checkpoint from the list of registered in the system.

Set-off of checkpoint is called fixing a particular CKPT in the system. The main idea of this offset is the detection of "false" checkpoints encountered on the route [4].

The approach is based on determining the time of finding the vehicle in the zone of the checkpoint.

2. Description of the algorithm for singling out flights from the actual events of the vehicle

The process of obtaining a set of actual flights from the actual events of the vehicle is called the process of singling out the actual flights. A feature of singling out is the need to determine the first and last actual flights in the shift interval to form the correct values of production and empty runs. The event refers to the shift, where more than half of the event took place (in time) [5].

In this case, the empty run per shift is equal to:

$$ L_x = l_{x1} + \sum_i l_{xi} + l_{x2} $$  \hspace{1cm} (1)

This can be expressed as follows:

A flowchart of the algorithm is shown in Figure 1. The basis in the algorithm is the determination of the start and end time for the interval of calculated events. This is due to the possible coincidence of checkpoint in actual flights with planned flights, related to different shifts, and as a result, the wrong result of comparing the planned and actual indicators of flights is obtained [6].

3. The algorithm for comparing planned and actual transportation figures indicators

The algorithm is used to control the route movement of freight or passenger vehicles performing transport work, which plan is presented in the form of a set of flights on specified routes. The purpose of the comparison is to provide adequate, complete information to the dispatcher about the progress of the transport process in real time to solve the problems of dispatching control and regulation of the transportation process [7].

The algorithm is applicable for monitoring and accounting of transport work in the presence of information about the planned tasks (flights) in the system. The input data should contain: information about the planned flights, including the times of the start of flights, the order and the points of the route, as well as information about the actual flights, which is obtained in the system by the algorithm for determining the navigation marks obtained from the navigation blocks. This information includes the correct management of reference information on mobile units, drivers, control points of the system, linking radio stations to mobile units. The output data are the compared planned and actual flights [8].
Figure 1. A flowchart of the algorithm for obtaining empty runs

Formalization of the process of movement of the vehicle in flight.

Initial data: information from the planning subsystem about the planned flights for each vehicle separately, ranked by the start time of each flight. Flights cannot overlap in time. We will designate a "scheduled flight" as a sequence of checkpoint, which the vehicle should visit in the process of transport work. In general, the term "flight" will be interpreted as a sequence of CKPT. There is at least one type of checkpoint in the flight of any type: type "fleet". Therefore, we take the designation of the CKPE type "fleet" as a $CKPT_F$ [9].

Figure 2. Sequence of scheduled flights
The figure shows the scheduled flights:
\[ P = (p_1, p_2, ..., p_n), \text{n-the number of scheduled flights} \]  \hspace{1cm} (2)

Here and further, the shaded areas correspond to objects of the "fleet" type, not shaded - "special object" items.

Each \( p_i \in P, i = 1, n \) is characterized by a set of attributes, the most significant of which are \( t_{pibeginning} \) and \( t_{piend} \). Each flight represents a sequence of checkpoints [10].

\[ T_{p_i}^{beginning} \]

\[ T_{p_i}^{end} \]

\[ P_i \]

\[ T \]

Figure 3. Time characteristics of a scheduled flight

The duration of the scheduled flight \( T_{p_i} \) is:
\[ T_{p_i} = T_{piend} - T_{pibeginning} \]  \hspace{1cm} (3)

where:
\[ T_{piend} = t_{pioutput}, l - \text{the number of checkpoints in shift} \]  \hspace{1cm} (4)

\[ T_{pibeginning} = t_{piinput} \]  \hspace{1cm} (5)

There may be scheduled flights with the same CKPT, so in general we have:
\[ p_i \cap p_j \neq \{ \}, i, j = 1, n \]  \hspace{1cm} (6)

Similarly, actual flights \( F \) are described.

With optimal planning of transport work in an ideal case, the vehicle should perform flights in the established order. Due to the fact that in the process of transport work the sequence and the set of checkpoints can change (operational planning on the one hand and disruptions in the process of transport work on the other), we define the following options (groups) of actual flights:

| № group | I group | II group | III group |
|---------|---------|----------|-----------|
| Interrelation | \( F\{f\} \cap P\{p\} \neq \{ \} \) | \( P\{p\} \subseteq F\{f\} \neq \{ \} \) | \( F\{f\} \cap P\{p\} = \{ \} \) |
| \( F\{f\} \cap P\{p\} = \{F\{f\}, P\{p\}\} \) | \( F\{f\} \cap P\{p\} \neq \{ \} \) | \( F\{f\} \cap P\{p\} \neq \{ F\{f\}, P\{p\}\} \) |

Method of comparing planned and actual flight information

To determine the degree of compliance of the work performed, it is possible to identify a number of criteria, which include: similarity criterion CKPT (k); the criterion of the minimum absolute deviation of the start time of each planned flight from each flight performed (t); the criterion of compliance with the sequence of passing checkpoints planned and completed flights (v). To solve the problem of determining the degree of correspondence between the actual and planned work, possible alternatives
\[ X = \{ x_p \} (p = 1, 2, \ldots, N_x) \] representing objects whose quality and efficiency are estimated by the vector index should be determined:

\[ w(x_p) = (w_1(x_p), w_2(x_p), \ldots, w_n(x_p)) \]

where \( w_1(x_p), w_2(x_p), \ldots, w_n(x_p) \) – private similarity functions;

Expressions for particular functions for this case of similarity of flights:

\[ K_\beta = w_1(x_p) = \left( \sum_{\alpha} k_{\alpha} \right)_\beta \rightarrow \text{extr}, \alpha = 1, r \]

\[ T_\beta = w_2(x_p) = \left( \sum_{\alpha} t_{\alpha} \right)_\beta \rightarrow \text{extr}, \alpha = 1, r \]

\[ V_\beta = w_3(x_p) = \left( \sum_{\alpha} v_{\alpha} \right)_\beta \rightarrow \text{extr}, \alpha = 1, r \]

Let object \( x_g \) be preferable (better) to the object \( x_h \) (denoted \( x_g \succ x_h \)) by \( w_k, k = 1, 2, 3 \) criterion if a strict \( w_k(x_g) > w_k(x_h) \) inequality is satisfied for the direct measurement scale and \( w_k(x_g) < w_k(x_h) \) for the inverse measurement scale. In this case, the problem of multi-criteria ranking (ordering) of objects evaluated by a set of indicators \( w_k, k = 1, 2, 3 \) can be posed. It is necessary to find such an ordering of objects \( x_{i1} \succ x_{i2} \succ x_{i3} \) satisfying condition \( w_k(x_{i1}) > w_k(x_{i2}) > w_k(x_{i3}), k = 1, 2, 3 \).

The described method of systematic optimization is reduced to the search for an extremum of a particular objective function on the set of admissible solutions obtained in the previous step. Figure 4 shows a flowchart of the main stages of assessing the performance of transport work based on the use of a step-by-step procedure for a variety of acceptable alternatives [11].

**Figure 4.** The procedure of step-by-step narrowing of the set of admissible alternatives

**4. Conclusion**

The article describes the basic algorithms for processing navigation data coming from vehicles performing transportation of goods or passengers on specified routes. The peculiarity of the considered algorithms is that they are equally applicable for the control of freight and passenger traffic, provided the description of the route in the form of an ordered sequence of checkpoints. Another feature of the
The developed algorithms provide a formal basis for the development of specialized software for automated dispatching control systems for cargo and passenger transportation.

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