INTELLIGENT SYSTEM FOR AUTOMATION SEARCH OF PUBLIC TRANSPORT ROUTES

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Summary
This article is devoted to automation of search of routes of passenger flows of inhabitants of the city on the basis of routes of public transport. To do this, it is proposed to use satellite data that reflect the movement of passengers. Based on the analysis of data arrays of information on the movement of cellular subscribers and the use of message messages to determine the effectiveness of passenger routes of public transport, the article proposes to create a system of automatic search of public transport routes, which includes different classes of charts and data bases. You can use data from cellular operators to do this. This can increase the accuracy of certain traffic volumes and the ability to monitor them in real time. Reliable information on the routes of urban public transport allows to determine passenger flows and efficiently perform transport services. The main requirements for modeling the city's passenger traffic are presented. Methods of obtaining data on determining the city's passenger traffic and public transport are considered. Documentation for the creation of the ISASR (Intelligent System for Automation Search of Routes) project has been developed. The MVC (Model-View-Controller) architectural template was used to develop the project. Class diagrams and precedent diagrams have been developed for the model. Database structures have been created and vehicle types and user types have been defined. Algorithms for finding routes for different situations, with different latitude and longitude coordinates, as well as different number of stops and transfers have been developed.

Keywords: GPS-sensor, data base, class diagrams, knowledge base, decision support, use case diagrams, satellite connection, model-view-controller.

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1. Introduction

To effectively manage and organize the operation of the public transport network, it is important to receive timely information about passenger flows within the territory covered by the network. The necessary condition is that such information should be received constantly on the basis of data monitoring, so-called "constant information". The availability of such information makes it possible to increase the level of service to users of public transport, for example, updating schedules with the offer of maximum convenience for users. In addition, this way you can attract additional users of public transport services.

As a rule, passenger flows are formed on the basis of previous research of correspondence of movements of inhabitants of the city. Calculation methods are used to determine and estimate the extent of travel correspondence. Socio-economic indicators of the population and the location of facilities within the transport planning area are usually used as source information in such calculations. In order to obtain sufficient reliable information about the movement of the population by public transport (tram, bus, etc.), it is necessary to involve a large number of experts and researchers, which in turn leads to time and material costs. It also affects the comfort of transportation and fatigue of passengers.

Due to the development of digital technologies and the proliferation of cellular networks, arrays of information about cellular subscribers' transactions have been increasingly used in recent years to determine and evaluate the extent of correspondence of passengers. In this way, you can ensure online monitoring and "continuity of information". Accurate linking of user movements to public transport routes (PTR) will make it possible to determine passenger flows and implement an efficient level of transport services. As a result, it can increase the accuracy of certain traffic extent and the ability to monitor them in real time. Given the above, automation the search for public transport routes is an actual task.

The aim of the work is to develop a system for automation the search for PTR using intelligent decision support. Achieving this goal is achieved by solving the following tasks:

– development of diagrams for the system of search of routes of passenger flows of public transport;
– development of structures and databases;
– description of data in class diagrams and databases;
– development of a route search algorithm.

2. Review of the literature

The problem of distribution of passenger movements in the city has been studied by many scientists. Having synthesized the available information on the planning of passenger flows, the process of transport planning of the city can be presented in the form of 4 stages:

Stage 1 – generating movement (trip generation);
Stage 2 – movement correspondence (trip correspondence);
Stage 3 – distribution of correspondence by type of movement (modal split);
Stage 4 – distribution by route of movement (network assignment).

Correspondence of movements is divided into groups: by purposes of movement; by choosing the type and route of movement. The main most important purposes of movement are: movement from place of residence to place of work (study) and back; movement from the place of residence to places of household and cultural services and in the opposite direction; movement between places of work (study) and / or places of household and cultural services.

The authors of the work *(Elkosantini & Darmoul, 2013)* conducted a study of the types of technologies that can be used to control public transport systems. The authors singled out such technologies as Traveler Information Systems, Geographic Information System, Automatic Vehicle Location System and Decision Support Systems. An overview of each of them, advantages and disadvantages. The authors note that it is important to integrate intelligent decision support systems into existing public transport planning architectures. This makes it possible to take into account all the events that may affect the operation of the network.

In the article *(Mnif et al., 2018)* the authors developed a semiheterarchical (hybrid), multiagent monitoring and control architecture the public movement of buses. Obstacles (accidents, congestion, etc.) are taken into account. The theory of immune memory, negative and clonal selection was used for development. This allowed to train the system on the basis of knowledge about violations during the movement of buses and to accumulate a knowledge base of the decisions made.

Subsequently, the work of this system was studied in *(Mnif, Elkosantini et al., 2019)*. In particular, performance was assessed using traffic simulation software. Time, passenger and service criteria were used to assess efficiency. It is proved that the performance of the system according to the criteria focused on passengers and service is much higher than the performance of the algorithms of control. Time-based criteria confirmed the performance of the proposed system better than the combination of waiting and passing stations.

For highways in Iran, the authors *(Ghanbari et al., 2015)* have developed an intelligent decision-making system that can significantly improve the transport infrastructure. The knowledge of road and transport experts was used in the development. Fuzzy logic methods and the Mamadani algorithm were used to teach the system. Simulation of the system was performed using the software environment Matlab. The authors note that the developed decision support system can be used in the initial design of intelligent urban and interurban transport lines.

In the article *(Szücs, 2015)*, the authors proposed to solve the transport problem using the Dempster-Shafer theory. Cost interval information for each route was used as a basis. An algorithm has been developed that allows determining the best route (the path with the lowest cost). It is important that the author of the article proposed the rules of the mechanism based on user requests. The use of this model allows you to make decisions to plan the route of the user network. This model is based on user decisions, in order to find a balance in optimizing the route where roads have uncertain attributes.

As an alternative to GPS, the authors of the article *(Salazar-Cabrera et al., 2020)* recommend the use of technology Bluetooth low energy and Radio-frequency identification to determine the positioning of vehicles. The advantage is that the cost of using such means of communication is lower than tracking a vehicle on the Internet. In addition, the article proposes to use long range technology to determine the positioning of vehicles. The architecture of the intelligent transport system for the city of Popayan (Colombian city) has been developed. The architecture takes into account waiting time at stops and energy consumption. This architecture contains the following main blocks: transportation information center, traffic management center, transit vehicle on-board equipment, traveler support equipment, personal information device, traveler, system operator and public vehicle operator.

The article *(Zannat & Choudhury, 2019)* presents the results of a review of current research papers on research in public transport route planning. The advantages and disadvantages of different methods and tools are considered. The article notes that most data is currently used to collect data from mobile devices, smart cards, which is much more convenient and cheaper than collecting information in traditional ways. The authors note that to take into account the interaction of public transport users with the environment, an extended mathematical model is needed, which will include machine learning tools and spatial statics integrated with spatial analysis.

3. Stages of development for the system of automation of searching PTR

To development the system for automation of search of PTR 4 stages are proposed:

Stage 1 – development of diagrams for the system of search of routes of passenger traffic of public transport;

Stage 2 – development of structures and databases;

Stage 3 – description of data in class and database diagrams;

Stage 4 – development of a route search algorithm.

In the further development of the project it is proposed to use the architectural template MVC (Model-view-controller).

In the first stage, it is proposed to develop a precedent diagram (usage diagram) and a class diagram using UML (Unified Modeling Language). UML is a notation system that should be used for object-oriented analysis and design. Can be used to visualize, specify, design and document software systems.

The class diagram shows the structure of the system with a description of the classes, their attributes, methods, and relationships between objects. The class has information about what the object might look like. That is, describes the state (attribute) and behavior (methods). The precedent chart shows the relationship between actors and precedents. It is an integral part of the precedent model, which allows you to describe the system at the conceptual level.

4. Development of diagrams

For the ISASR (Intelligent System for Automation Search of Routes) project, documentation must first be developed, and a plan must be provided. So, first let's define the types of transport that should be supported: minibus; bus; trolleybus; tram. Then define the users of the developed system: passenger; the driver; carrier; dispatcher.

Next we move on to the technical part. The model is represented by the following diagrams:

1. Use case diagrams – in UML (Unified Modeling Language), a diagram showing the relationship between actors and precedents in the system. It also translates as a usage chart.

2. Class diagrams – is used to represent the static structure of the system model in the terminology of object-oriented programming classes. This diagram shows classes, interfaces, objects, and cooperatives, as well as their relationships.

Use case diagrams. The scheme of the diagram is shown in Fig. 1.

User interacts with the ISASR system through the following uses:

– From location – the starting point from which the user intends to move;

– To location – the end point of movement;

– By location – an intermediate point through which the user has the desire (need) to move;

– Go – notifies the system to start paving the route;

– Schedules – gives the user access to schedules;

– Routes lists – displays lists of routes available in the database (if the user searched for routes by location, displays found, otherwise all);

– Stops list – displays stops as a list;

– Show all stops – all stops should appear on the map;

– Stops on / off – show / not show stops on the drawn route (s);

– Add / delete database – gives the user access to download new and delete existing databases;

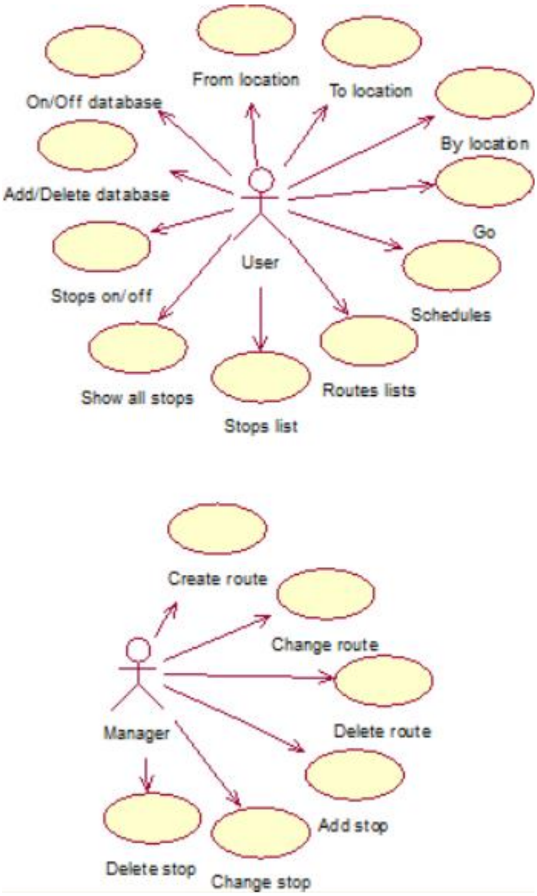

Fig. 1. Use case diagrams

– On / off database – determines in which databases the search will take place (will be active).

– Save database – saves the user database.

– Unload database – downloads the user database for exchange.

Manager interacts with the ISASR system through the following uses:

– Create route – gives the manager access to the route editor to create a new route (only one database must be active for editing).

– Change route – gives the manager access to the route editor for editing existing ones (only one database must be active for editing).

– Delete route – allows the manager to delete the route (only one database should be active for editing).

– Add stop – allows the manager to add a stop to the created (edited) route or create a stop in the edited database (only one database should be active for editing).

– Change stop – allows the manager to edit the stop in the edited database (only one database should be active for editing).

– Delete stop – allows the manager to delete a stop on the created (edited) route or delete a stop in the edited database (only one database should be active for editing).

– Create database – gives the manager the opportunity to create a new database.
– Change database – gives the manager the ability to edit an existing database.
– Delete database – allows the manager to delete the database.
– Unload database – allows the manager to download the database to the server.

Class diagrams. The scheme of the diagram is shown in fig. 2. The following types of notation were used in the development of the diagram: association and dependence.

The multiplicity can be set equal to one (1), you can specify the range: "zero or one" (0..1), "many" (0 .. *), "one or more" (1 .. *). It is also allowed to specify a certain number *(for example, 3)*. Using the list, you can specify more complex multiplicities, such as 0.. 1, 3..4, 6 .. *, which means "any number of objects except 2 and 5".

ClassTransport – contains properties (variables) and methods (functions) intended for general work; saves, searches, and draws routes and stops.

ClassDbController – designed for database control.

EnumRouteState – a list of directions in which you move along the route (forward, reverse, in both directions).

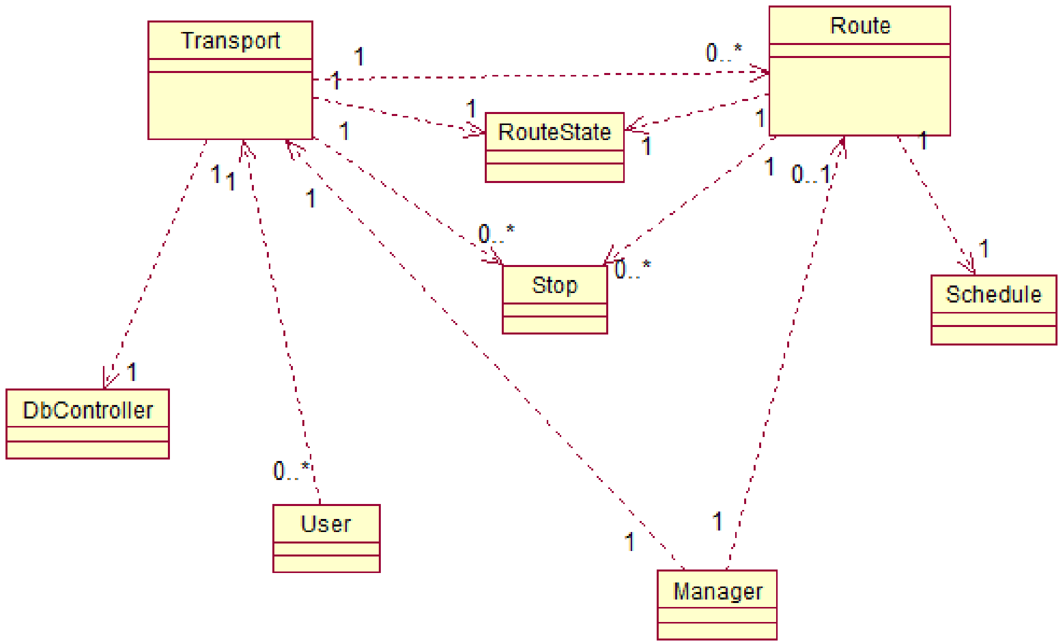

Fig. 2. The structure of the class diagram

ClassUser – contains properties (variables) and methods (functions) intended for the operation of the user part, performs primary processing of user information and redirects (if necessary) data for further processing to transport classes DbController.

ClassManager – contains properties (variables) and methods (functions) intended for the work of the manager: creating / editing / deleting databases \ routes / stops, sends requests to the class Transport data update and class DbController to load the database to the server.

ClassRoute – contains properties (variables) and methods (functions) designed to work with the route, information about the route and locations through which it passes.

ClassStop – contains properties (variables) and methods (functions) designed to work with a stop, location and name.

Class Schedule – contains the route schedule.

5. Development of structures and databases

Three databases have been developed:

– UserDbs.db – databases that can be downloaded or activated;

– Country-City.db – database of a specific city;

– UserShareDb.db – user database with saved places: jobs, places of residence, shopping, leisure, etc.

UserDbs.db. The structure of this database is shown in Fig. 3.

Country-City.db. The structure of this database is shown in Fig. 4.

UserShareDb.db. The structure of this database is shown in Fig. 5.

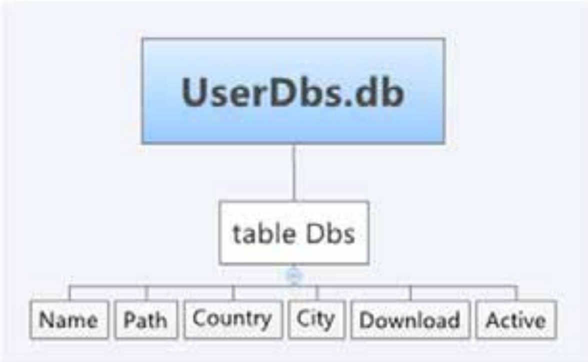

Fig. 3. UserDbs.db database structure

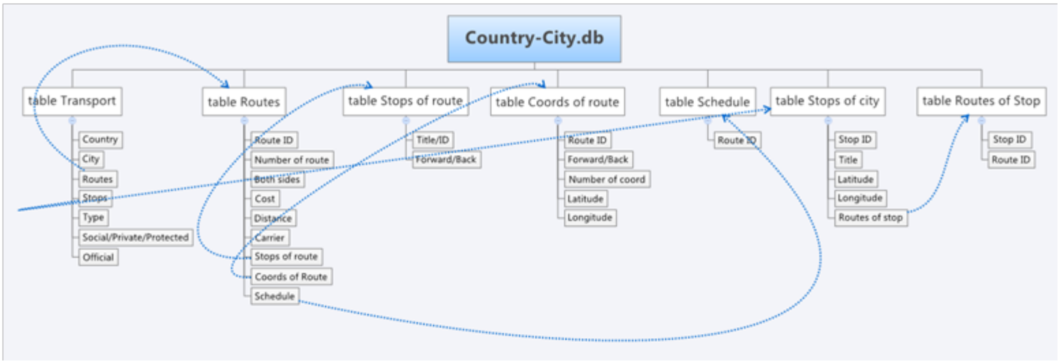

Fig. 4. Structure of the Country-City.db database

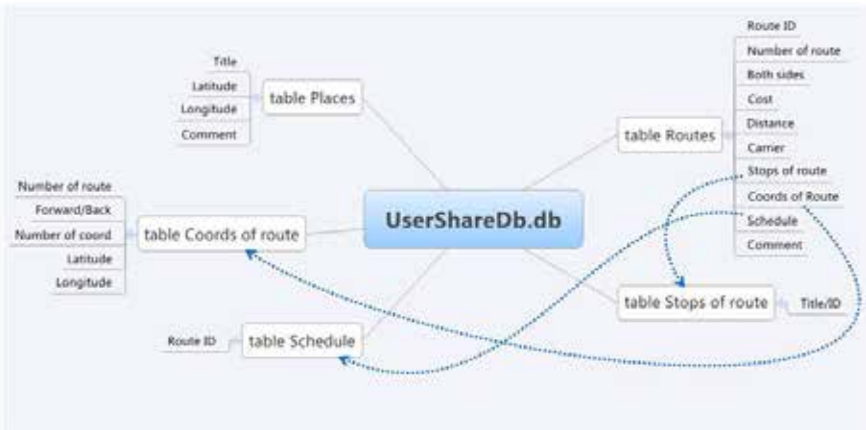

Fig. 5. UserShareDb.db database structure

The STD (State Transition Diagrams) diagram is shown in Fig. 6.

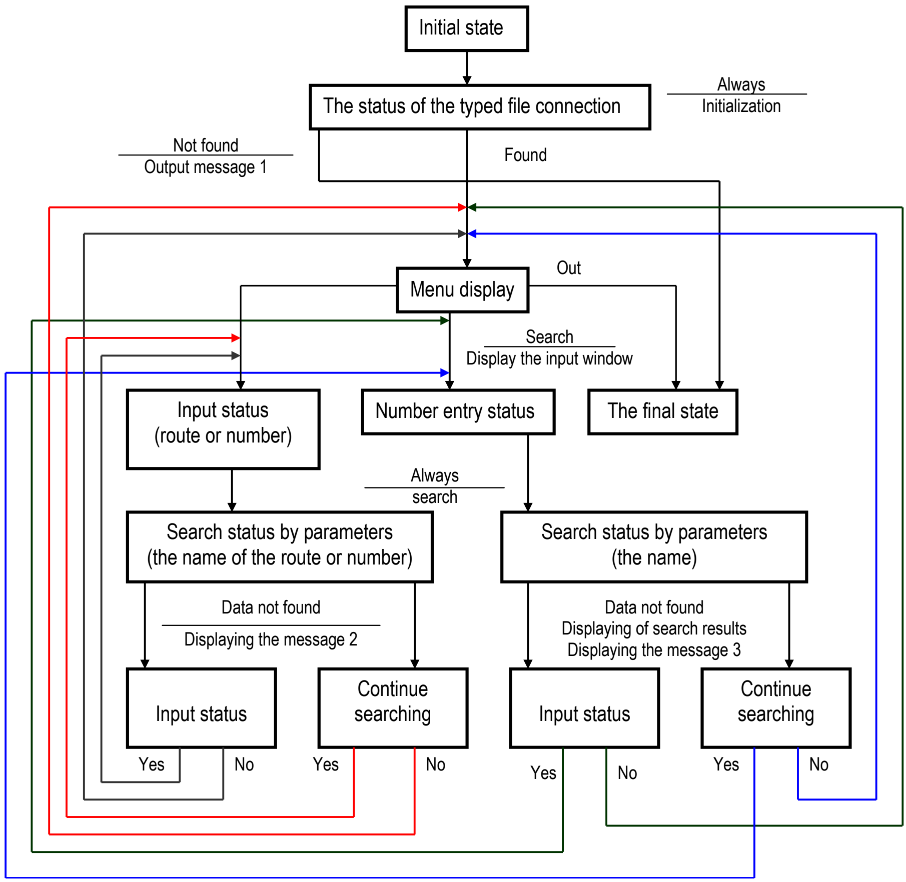

Fig. 6. State transition diagram (STD diagram)

STD-diagrams are designed to model the operation of the system, taking into account its operation in previous and current stages. Thus, the system for which the simulations are performed can be in one particular state at any time among an infinite number of these states. The system can change its state after a certain time interval, but it is necessary to take into account that the transitions between the states of the system were precisely defined.

Message 1: "Typed file not found. Provide the name and path to the file or enter data from the keyboard".

Message 2: "Data not found. Repeat search? Yes No".

Message 3: "Continue searching? Yes No".

The main operations are: menu output; initial state; final state; search status by parameters; input status; continue search.

6. Data presentation

According to the diagrams of precedents and classes, as well as database structures, for the visual implementation of the system developed a presentation of information for diagrams and databases. The presentation of Class diagrams data is shown in Fig. 7.

Fig. 7. Data presentation Class diagrams

ViewUserMap – displays the map and allows the user to specify the points (locations) of departure, arrival and, if necessary, the intermediate location.

ViewFind – displays a list of found routes or immediately draws the optimal route.

ViewChangeDelete – allows the user to select (download) databases, with activated manager mode to edit / delete databases, routes and stops.

ViewProperties – allows the user to change the default route search settings.

ViewManagerMap – displays the route editor (stops).

The presentation of information in the Controllers block is shown in Fig. 8.

UserMapController is a control model between the ViewUserMap view and the data.

UserSearchController is a control model between the ViewFind view and the data.

PropertiesController is a control model between the ViewProperties view and the data.

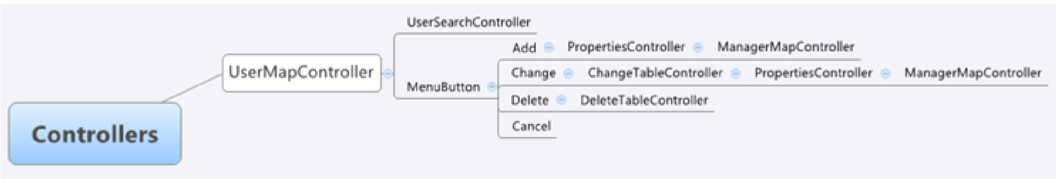

Fig. 8. Presentation of information in the Controllers block

ChangeTableController is a control model between the ViewChangeDelete view and the data.

DeleteTableController is a control model between the ViewChangeDelete view and the data.

ManagerMapController is a control model between the ViewManagerMap view and the data.

7. Algorithms for finding routes

Several route search algorithms have been developed:
- algorithm for finding routes by stops;
- algorithm for finding routes by stops with transfers;
- algorithm for finding routes by coordinates;
- algorithm for finding routes by coordinates with a change.

Algorithms take into account:
- latitude and longitude of the location;
- search for stops;
- route search;
- sorting of found routes;
- display of the most attractive route;

In fig. 9, fig. 10, fig. 11 and fig. 12 are block diagrams of route search algorithms for different situations, with different latitude and longitude coordinates, as well as different number of stops and transfers.

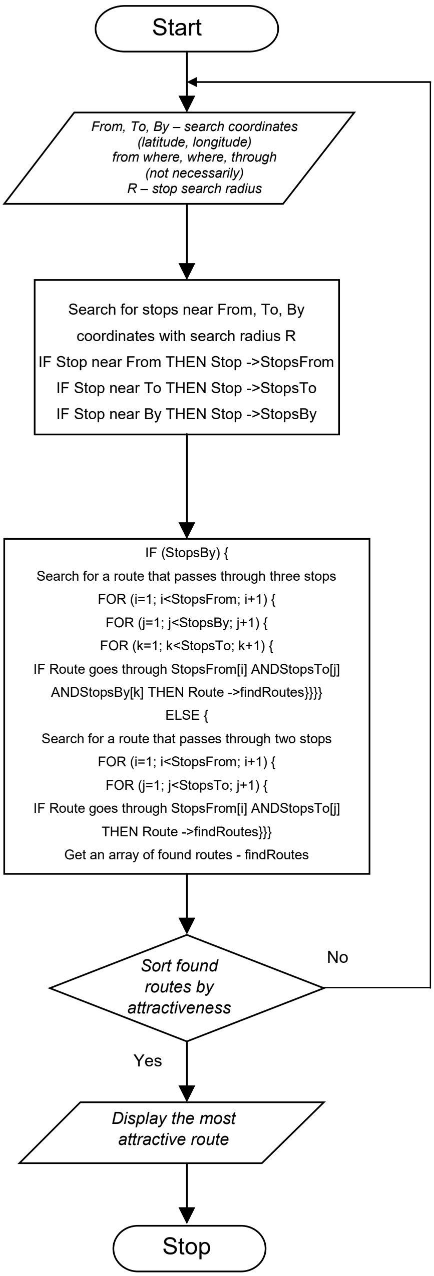

Fig. 9. Algorithm for finding routes by stops

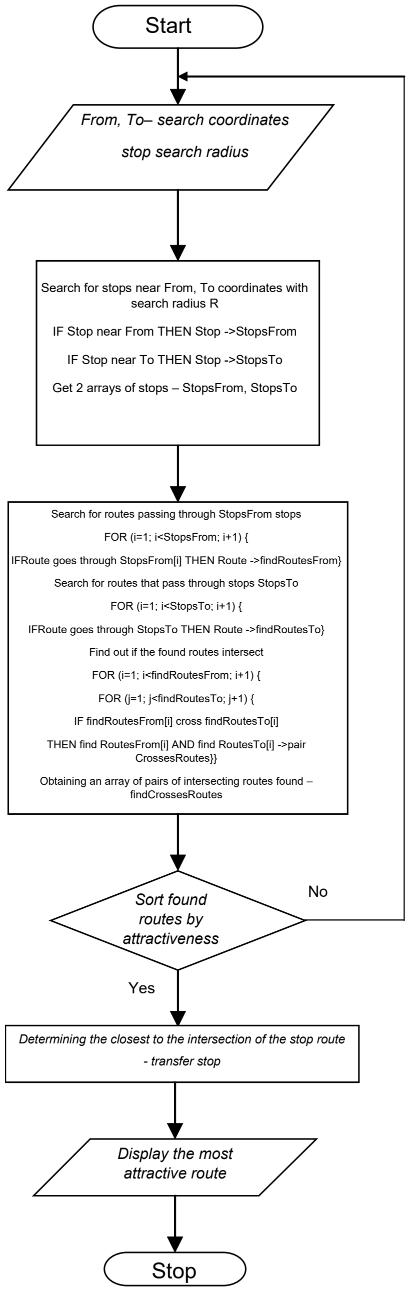

Fig. 10. Algorithm for finding routes by stops with transfers

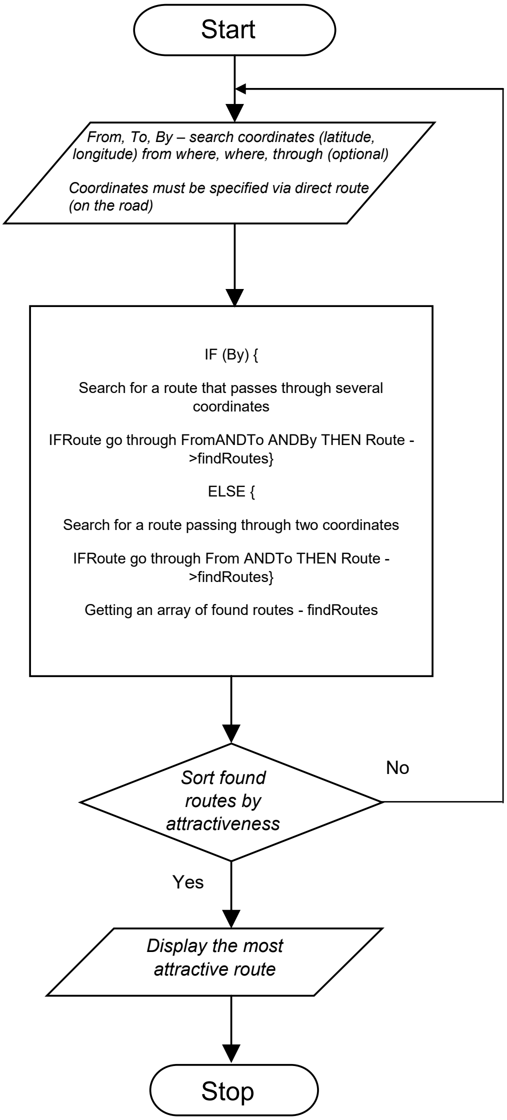

Fig. 11. Algorithm for finding routes by coordinates

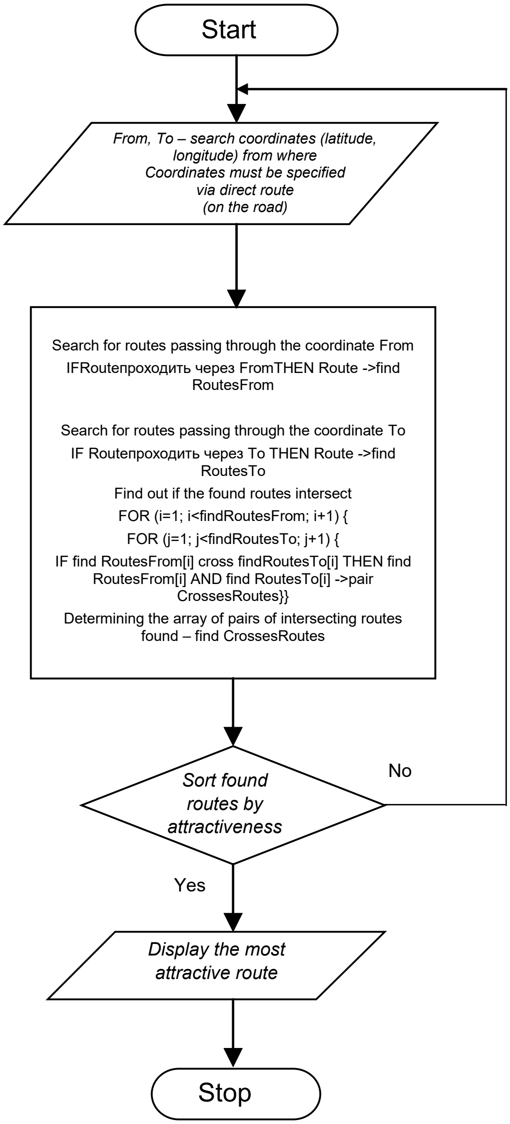

Fig. 12. Algorithm for finding routes by coordinates with transfers

According to the algorithms shown above, the automatic route search consists of entering the search coordinates From, To, By with the corresponding search radius R. Then using the calculation unit determines the available route options (according to the entered coordinates) and gets data sets. Then the search for the most attractive routes takes place and the corresponding data set is formed. In the resulting data set, you can sort routes by attractiveness (according to certain criteria (route duration, route length, etc.)). Then the most attractive route is shown on the display. In the future it is planned to develop software and user interface for this project.

8. Conclusions

Developed route search algorithms can be adapted to different vehicles, not just public transport. These diagrams and structures are part of an intelligent search for routes for public transport passengers. For the practical implementation of this system requires the availability of special technical means (Smartphone, mobile phone, trackers, etc.). The system provides databases, including UserShareDb.db – a database of users with saved jobs, accommodation, shopping, leisure, etc.

The developed model of choosing an alternative route for the population of the city takes into account the cost of travel on the route, the average interval of vehicles and the fullness of the vehicle. The determining criterion in choosing a rational (effective) option is the attractiveness of the route. The most attractive route will be the one for which his score will be the highest among others.

References

1. Elkosantini, S., & Darmoul, S. (2013). Intelligent Public Transportation Systems: A review of architectures and enabling technologies. У 2013 international conference on advanced logistics and transport (ICALT). IEEE. https://doi.org/10.1109/icadlt.2013.6568465 [in English].

2. Ghanbari, M., Mehr, A. G., & Nehzat, H. (2015). Introducing an intelligent transportation system decision support model for the highways in Iran based on fuzzy logic. International Journal of Soft Computing and Engineering (IJSCE), 3(5), 101–104. URL: https://www.researchgate.net/publication/304022544_Introducing_an_Intelligent_Transportation_System_Decision_Support_Model_for_the_Highways_in_Iran_Based_on_Fuzzy_Logic (date of access: 19.01.2022) [in English].

3. Mnif, S., Darmoul, S., Elkosantini, S., & Ben Said, L. (2018). An immune multiagent system to monitor and control public bus transportation systems. Computational Intelligence, 34(4), 1245–1276. https://doi.org/10.1111/coin.12181 [in English].

4. Mnif, S., Elkosantini, S., Darmoul, S., & Ben Said, L. (2019). An immune network based distributed architecture to control public bus transportation systems. Swarm and Evolutionary Computation, 50, 100478. URL: https://doi.org/10.1016/j.swevo.2018.12.004 [in English].

5. Salazar-Cabrera, R., Pachón de la Cruz, Á., & Madrid Molina, J. M. (2020). Sustainable transit vehicle tracking service, using intelligent transportation system services and emerging communication technologies: A review. Journal of Traffic and Transportation Engineering (English Edition), 7(6), 729–747. https://doi.org/10.1016/j.jtte.2020.07.003 [in English].

6. Szücs, G. (2015). Decision support for route search and optimum finding in transport networks under uncertainty. Journal of Applied Research and Technology, 13(1), 125–134. https://doi.org/10.1016/s1665-6423(15)30011-0 [in English].

7. Zannat, K. E., & Choudhury, C. F. (2019). Emerging big data sources for public transport planning: A systematic review on current state of art and future research directions. Journal of the Indian Institute of Science, 99(4), 601–619. https://doi.org/10.1007/s41745-019-00125-9 [in English].