Intelligent Real-Time Vehicle Tracking Information System

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Abstract 1

This project is devoted to developing an intelligent information system for real-time vehicle tracking using the event streaming platform to achieve high performance. It provides studying and practical use of real-time data processing in large amounts, building a resilient, fault-tolerant, and high availability service. The main objective was to design and create the system to allow its users to operate, observe, and track vehicles in real-time. The real-time tracking system allows fleet management functions such as fleet tracking, routing, dispatching, on-board information, and security. It helps users identify and track the location of objects or people in real-time. It is used everywhere in transport and logistics in various industries. The postmodern tracking system requires an open architecture and high scalability. An ideal real-time location system can accurately track, inventory, locate, and manage assets, or people and help companies make informed decisions based on collected location data.

Research methods are the analysis and comparison of vehicle GPS data flow methods in transport areas, the construction and building of an application, integrated with certain third-party services and platforms. One of the goals was to provide the absence of downtime, the possibility to process a large amount of data, improve scalability, and so on.

The server part of the system that processes the incoming data was built using Java programming language and Spring Framework. As an event streaming platform, Kafka was chosen. For storing and processing all the data, there was used Hibernate as a database ORM. There were selected third-party React libraries on the client-side to interact with the client and show the GPS data and the vehicle information on a map. During development, IntelliJ IDEA was used as IDE. The object of the study is the integration mechanisms and functionality of GPS data in interaction with real-time event streaming. Scope of research – the processes of development, integration, the exchange of information systems with GPS data flow using the GUI client. The study aims to demonstrate and analyse the functionality of a real-time vehicle tracking system that can support high loads.

There were main problems of the GPS data processing investigated. The main advantages and disadvantages of the created system were determined. During the implementation, there were analysed few services that have similar functionality, benefits, and weaknesses.

In the analysis process, the system itself was analysed "as is", which means the external environment and the design were determined. The plan was decomposed, and the business processes were found out, that all was shown using notation objects (UML).

The developed system covers all the user's basic needs to track vehicles in real-time using a web browser. The proof of concept of the system with the finished lifecycle of IT-project development results from this diploma project.

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Keywords
Tracking system, GPS, real-time, vehicles, process optimisation, real-time data processing, application program interface, vehicle tracking, information system, artificial intelligence, web application, machine learning, neural network, rating vector priority, vehicle tracking device, decision making, system analysis

1. Introduction

Many production processes and supply chains depend on reliable, authentic and up-to-date real-time information. But other innovation scenarios could not exist without real-time object tracking systems [1-3]. For example, they are driving together, sharing a car or delivering food, etc. The real-time tracking system allows you to identify and track the location of objects or people in real-time [4-8]. It is used everywhere in transport and logistics in various industries [9-12]. The postmodern tracking system requires an open architecture and high scalability. An ideal real-time location system can accurately locate, track, and manage assets, inventory, or people and help companies make informed decisions based on collected location data. An essential requirement of modern object tracking is the ability to integrate with different technologies. These include location tracking technologies such as radio frequency (RF), infrared (IR), RFID, beacon, Wi-Fi, Bluetooth, UWB, GPS, GSM, 5G, and more. It should also be noted that the system must be reliably integrated with the rest of the enterprise in real-time. These include MES, ERP, APS, CRM, data lakes and many other applications. The program should include [1-12]:

- Fleet tracking - vehicle tracking systems allow the company to track the location and speed of the car, optimise routes, plan tasks, help navigation and analyse driver efficiency;
- Navigation - the most basic navigation services contain instructions on moving from point A to point B. The inclusion of GPS, mapping and mobile cellular technologies will provide more sophisticated navigation services;
- Inventory and asset tracking - RFID technologies are widely used for asset and inventory tracking. RFID tags communicate wirelessly with RFID readers across the enterprise.

The urgency of the work stems from the widespread popularity of the use of GPS data in everyday life by people in their smartphones or large companies to control the fleet. *The work aim*s to demonstrate and analyse the functionality of the vehicle tracking system in real-time, which can withstand high loads. It will allow you to explore the business scope of such applications and specific functionality.

To achieve this goal, the following tasks were identified:

- Acquaintance and analysis of functions and means of communication that represent existing solutions;
- Research and comparison of existing systems that have similar functionality and use similar technologies to process information or interact with the user;
- Building and demonstrating an application that is ready to use and interacts with the necessary customised services.

GPS fleet tracking is commonly used in almost every industry, although usage depends on the situation in each business.

For example, in the construction industry, fleet tracking is used to ensure the proper use of equipment in the workplace. It is a viable way to manage fuel costs and compliance in retail and manufacturing, allowing managers to transport and deliver products reliably, efficiently and on time.

It is also often used for services and special auctions, helping to ensure that employees get to work on time through job applications and make sure they can use all vehicles.

The object of the study is an application for vehicle tracking in real-time and its functionality.

The research subject is the processes of development, integration, and interaction of information systems with GPS data. *The research methods* are a way to use real-time vehicle tracking systems in logistics, building an existing service integrated with certain third-party services and platforms.

The scientific novelty of this work is to build an information system for processing GPS data in real-time, with the possibility of integration into existing systems.

The practical significance of the work results lies in the popularity of GPS data and their visualisation in real-time, and the apparent imperfections of existing systems.

2. Related works

2.1. Basic principles of research

In today’s world, it is often just necessary to get up-to-date information. It also applies to vehicles in areas such as logistics [13-14]. At the moment, there are many tools to solve such a problem as real-time vehicle tracking [15-21]. Still, in addition, most of them can be attributed to certain shortcomings, such as long delays in obtaining information, monolith city, patentability, limited scalability, single-purpose decision. GPS vehicle tracking is a sophisticated solution that allows you to locate your vehicle by connecting to a global positioning system. Typically, this system takes the form of a vehicle tracking device capable of using GPS technology, real-time tracking and instant data transfer to a connected mobile application [22-25]. Yes, modern vehicle tracking solutions are not only easy to use but also entirely accurate. Under normal conditions, you can get real-time location information up to three meters. In addition, the accuracy of data transmitted from vehicle tracking devices depends on satellite signals, which can be worse in large cities due to large buildings. The more open the sky over the object you want to track, the more accurate the data will be.

The primary functional system is integrated into the tracking and analysing data received from vehicles using satellite signals. There are two monitoring options:

- Online - data is received remotely;
- Offline - the information is read when reaching a specific place.

The tracking system allows you to control the movement of vehicles and control the amount of fuel to monitor some techniques and even mechanisms. Thus, you can track which route the car follows, its mileage, speed and observe the skills of the driver and the condition of the vehicles.

The systems use GPS and GSM technologies to provide accurate and consistent telematics for the individual fleet manager. These systems are usually equipped with monitoring statistics, such as; fuel consumption, average speed, current driver time and location [26-27]. Demand for this technology has recently increased as EU regulations impose stricter limits on when a driver can work on a given day. It is currently limited to 9 hours a day. Companies are legally required to install a tachograph in any vehicle that carries goods [28-29]. This obligation has led many to burn this potentially burdensome obligation instead of turning it into a benefit. Park management systems use GPS and GSM technologies. Like other trackers, although due to their nature, they are equipped with more specific diagnostic functions.

2.2. Known means analysis of solving the problem

Let’s consider the following systems in the segment of real-time vehicle tracking: Verizon Networkfleet, Fleetistics, Nextraq, Rhino Fleet Tracking, Teletrac.

Verizon Networkfleet provides cost-effective fleet management solutions for government agencies, small and medium-sized businesses and businesses. The advantages of this service include a variety of functionality, the ability to track driver behaviour, such as speeding, idling, driving stiffness. It is also possible to keep statistics on fuel consumption and reduce maintenance costs. The service can improve the routing and visibility of the fleet. The disadvantages of the system include the complexity of solutions, which may not always be suitable for small businesses.

Fleetisticsis an inexpensive and straightforward GPS tracker with the ability to upgrade and scale when the fleet increases in size and complexity. Integrated fleet management increases efficiency, productivity and profitability. Integrated partners provide a modular approach to fleet management.

The advantages of this service are its availability for light and medium businesses, a wide range of features, the ability to view the movement’s history. The system is based on the Cloud solution and is implemented as Software-as-a-Service, i.e. the only access to it is a browser.

Nextraq is a cloud application for service and distribution business to optimise the performance of vehicles. The service is multifunctional, allows the user to track, report, plan routes and more.

The advantage of this service is it is multiplatform. It can be used in a web browser, desktop application, mobile phone and more. It is designed for all types of customers - from small businesses to businesses. Disadvantages include the fact that their users receive information about the untimely update of the status of vehicles, a rather complex interface, which must first be understood. They also have some problems with technical support.

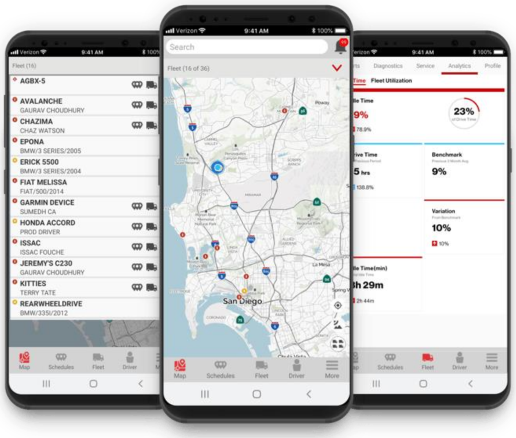


Figure 1: Verizon Networkfleet application view

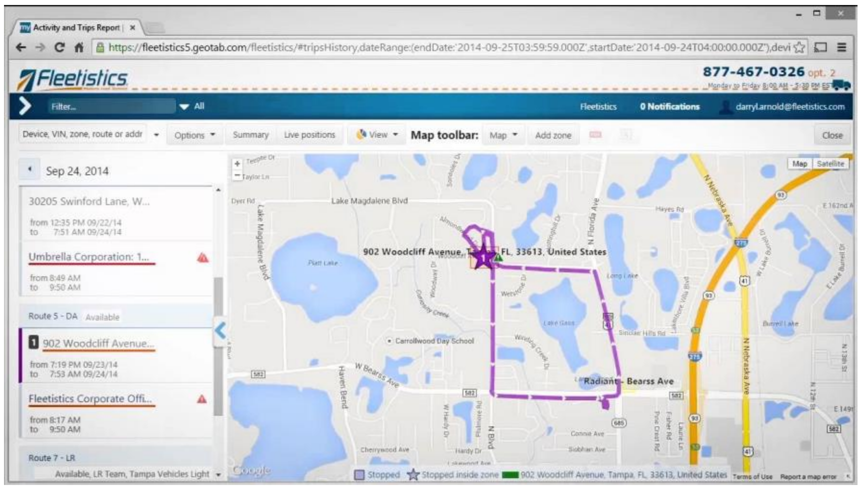


Figure 2: View of the Fleetistics system

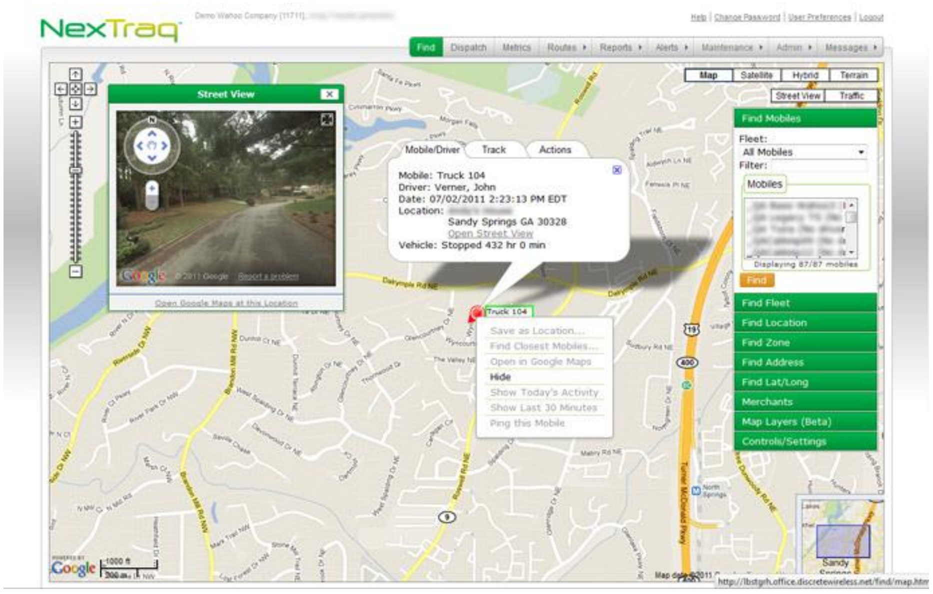
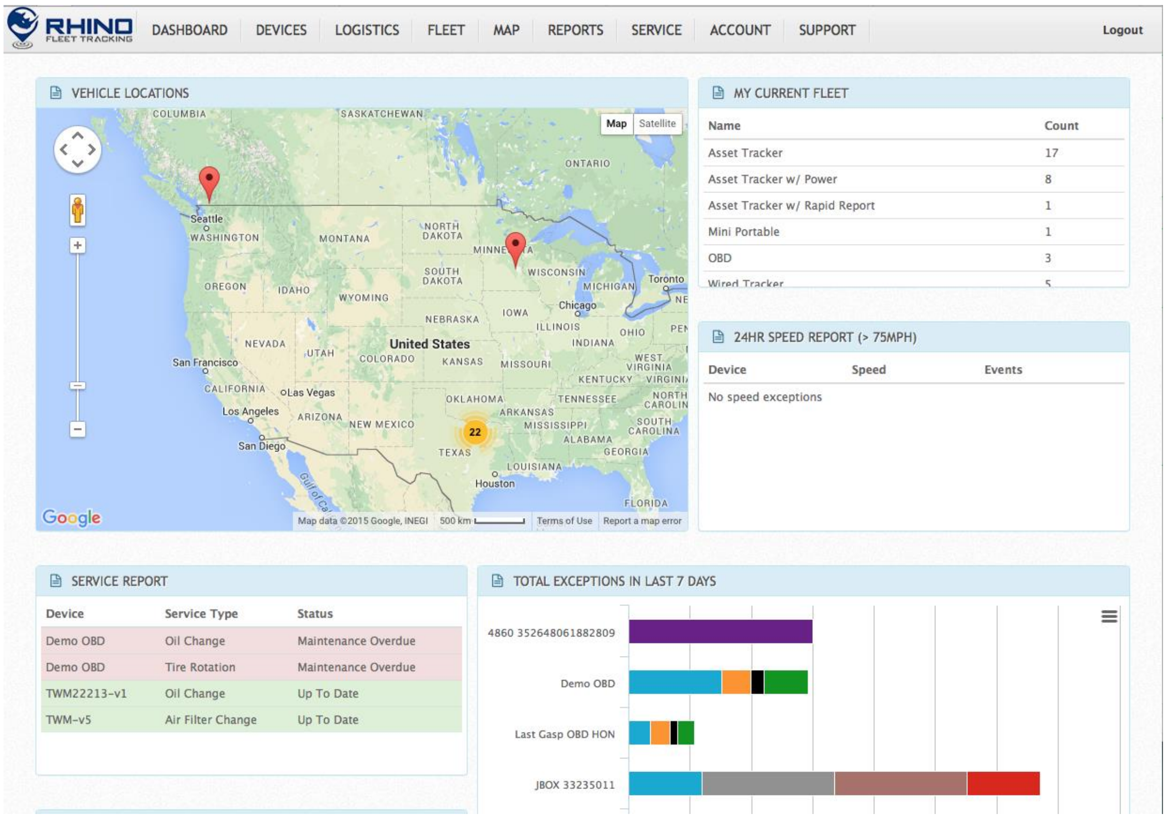


Figure 3: View of the Nextraq system

Rhino Fleet Tracking is a vehicle tracking system of any type based on cloud servers. The software also offers fleet maintenance tools and is compatible with desktop and mobile devices. Rhino Fleet Tracking uses GPS trackers to monitor vehicle location and display routes in real-time using Google Maps. The integration of HOS and ELog helps users determine how long drivers have been on the road, which helps maintain FCMSA requirements. Feedback can also be sent to the driver monitoring device.

The strength of this service is a user-friendly, easy-to-use interface, data visualisation using Google Maps. Sometimes the versions of the card are outdated, which affects the operation of the service itself. The service itself, from time to time, works with errors.



MY CURRENT FLEET

Name	Count
Asset Tracker	17
Asset Tracker w/ Power	8
Asset Tracker w/ Rapid Report	1
Mini Portable	1
OBD	3
Wired Tracker	5

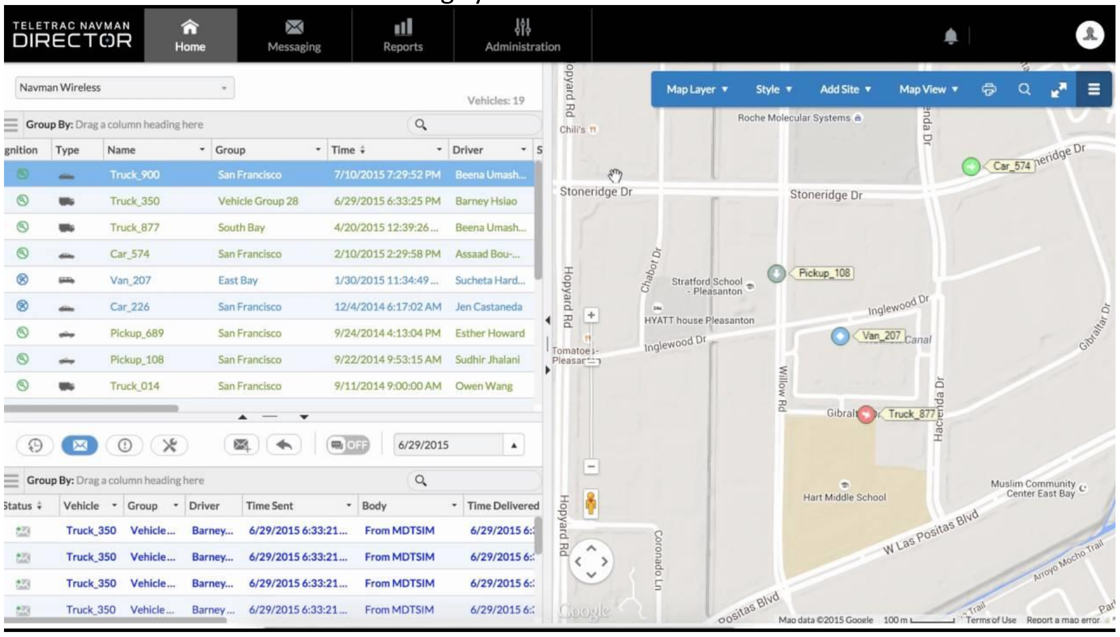
24HR SPEED REPORT (> 75MPH)

Device	Speed	Events
No speed exceptions		

SERVICE REPORT

Device	Service Type	Status
Demo OBD	Oil Change	Maintenance Overdue
Demo OBD	Tire Rotation	Maintenance Overdue
TWM22213-v1	Oil Change	Up To Date
TWM-v5	Air Filter Change	Up To Date

Figure 4: View of the Rhino Fleet Tracking system



Navman Wireless

Vehicles: 19

Group By: Drag a column heading here

gnition	Type	Name	Group	Time	Driver
		Truck_900	San Francisco	7/10/2015 7:29:52 PM	Beena Umash...
		Truck_350	Vehicle Group 28	6/29/2015 6:33:25 PM	Barney Hsiao
		Truck_877	South Bay	4/20/2015 12:39:26 ...	Beena Umash...
		Car_574	San Francisco	2/10/2015 2:29:58 PM	Assaad Bou-...
		Van_207	East Bay	1/30/2015 11:34:49 ...	Sucheta Hard...
		Car_226	San Francisco	12/4/2014 6:17:02 AM	Jen Castaneda
		Pickup_689	San Francisco	9/24/2014 4:13:04 PM	Esther Howard
		Pickup_108	San Francisco	9/22/2014 9:53:15 AM	Sudhir Jhalani
		Truck_014	San Francisco	9/11/2014 9:00:00 AM	Owen Wang

6/29/2015

Group By: Drag a column heading here

Status	Vehicle	Group	Driver	Time Sent	Body	Time Delivered
	Truck_350	Vehicle...	Barney...	6/29/2015 6:33:21...	From MDTSIM	6/29/2015 6:
	Truck_350	Vehicle...	Barney...	6/29/2015 6:33:21...	From MDTSIM	6/29/2015 6:
	Truck_350	Vehicle...	Barney...	6/29/2015 6:33:21...	From MDTSIM	6/29/2015 6:
	Truck_350	Vehicle...	Barney...	6/29/2015 6:33:21...	From MDTSIM	6/29/2015 6:

Figure 5: View of the Teletrac system

Teletrac has a wide range of virtually comprehensive features but also customisable, allowing fleet managers to choose which parts they deem necessary. As a result, any fleet can find a version that works for their specific needs, no matter how small or large the customer's number of vehicles. Managers can view their fleet with an aerial satellite view, a list of vehicles that can be clicked, and a GPS map, and they can even get a street view with instant playback of the DVR (provided the car has it) installed). Among the advantages is communicating with dispatchers and vice versa, vehicle diagnostics, driving safety warnings and more. The disadvantages include the fact that the service functions are minimal if the user has a cheap plan limited fuel card integrations. There is no free trial, just a free demo.

2.3. Software system functionality

The functionality of the system that needs to be designed:

1. Filling the system with the necessary information that will be used by the system itself (list of vehicles, database initialisation);
2. Infrastructure configuration - deployment of a platform for streaming events to ensure the relevance of GPS data; interactivity - help the user to use the provided functionality of the service;
3. Providing a wide choice of functionality to meet all user needs;
4. The ability to view the status of vehicles at any time and the relevance of information;
5. Authorisation and authentication - the user can log in to the system, as well as be recognised in subsequent sessions;
6. Shared architecture for possible further integration of other users, the ability to share responsibilities between managers and supervisors;
7. Availability in the database of all necessary information for the stable operation of the system;
8. Creating an admin panel to manage the system and change the configuration;
9. Providing an intuitive user interface;
10. Informing the user about events or errors using the notification system;
11. Application software interface (API) for communication with systems;
12. Processing of already available information in databases;
13. Possibility of geo-zoning, creation of event processing, reading of data from the devices connected to the vehicle, etc.;
14. The ability of the system to process user requests that are not provided.

Table 1
Attributes of functions

Function	Status	Priority	Labour Int.	Risk	Stability	Version
1	Included	Critical	Average	Low	Average	0.2
2	Included	Critical	High	Average	High	0.2
3	Included	Critical	High	Average	Average	0.4
4	Included	Critical	High	Average	Average	0.6
5	Approved	Important	Average	Average	Average	0.6
6	Included	Important	High	Low	Low	1.0
7	Approved	Critical	Low	Low	Low	0.4
8	Approved	Important	Average	Average	Low	0.6
9	Approved	Important	High	Low	Average	1.0
10	Included	Useful	Average	Average	Average	1.2
11	Included	Useful	Average	Low	Low	1.2
12	Approved	Useful	Low	Low	Low	1.2
13	Included	Useful	High	High	Average	1.4
14	Included	Useful	Average	Average	Average	1.8
15	Approved	Useful	Average	Average	Average	2.0

Vehicle tracking systems are top-rated and in high demand. Even considering developing a high-level strategy, we can conclude that the development of its specialised tracking system may require research and solving quite complex problems.

3. Materials and methods

3.1. System analysis of the object of study and its subject area

The objects of informatisation should include users, developed systems, control of defects. The purpose of the system is to create a chatbot [30-35] and interactive elements for the information system of forming a list of clothes according to the user's request. First of all, you need to create a configuration file for the design, which allows you to flexibly manage the entire service, such as changing the data to access the database. The next step is to select and connect a system for processing the user's natural language and select a messenger that will serve as an ecosystem for the chatbot [30-35]. The successful implementation of any software depends on many factors. An important link is a clear understanding of the purpose, goals and problems that the system must solve. In addition, you need to have knowledge and experience of how you can solve problems to achieve goals.

The basis of the systems analysis methodology is the choice of alternatives and comparison of quantitative characteristics during decision-making. To quantify estimates, it is first necessary to meet the requirements of qualitative evaluation criteria and define them.

A "goal tree" is a specific visual representation of the relationship and sequence of goals representing the division of the mission and the main goal of the task by breaking it down into sub-goals or individual actions [36-38]. Fig. 6 shows the tree of goals of the system considered in this work, a service designed to operate the vehicle tracking system in real-time. According to the presented tree of purposes, the service pursues four primary goals ensuring ease of use, the relevance of information, the stability of the system, the adequacy of the service.

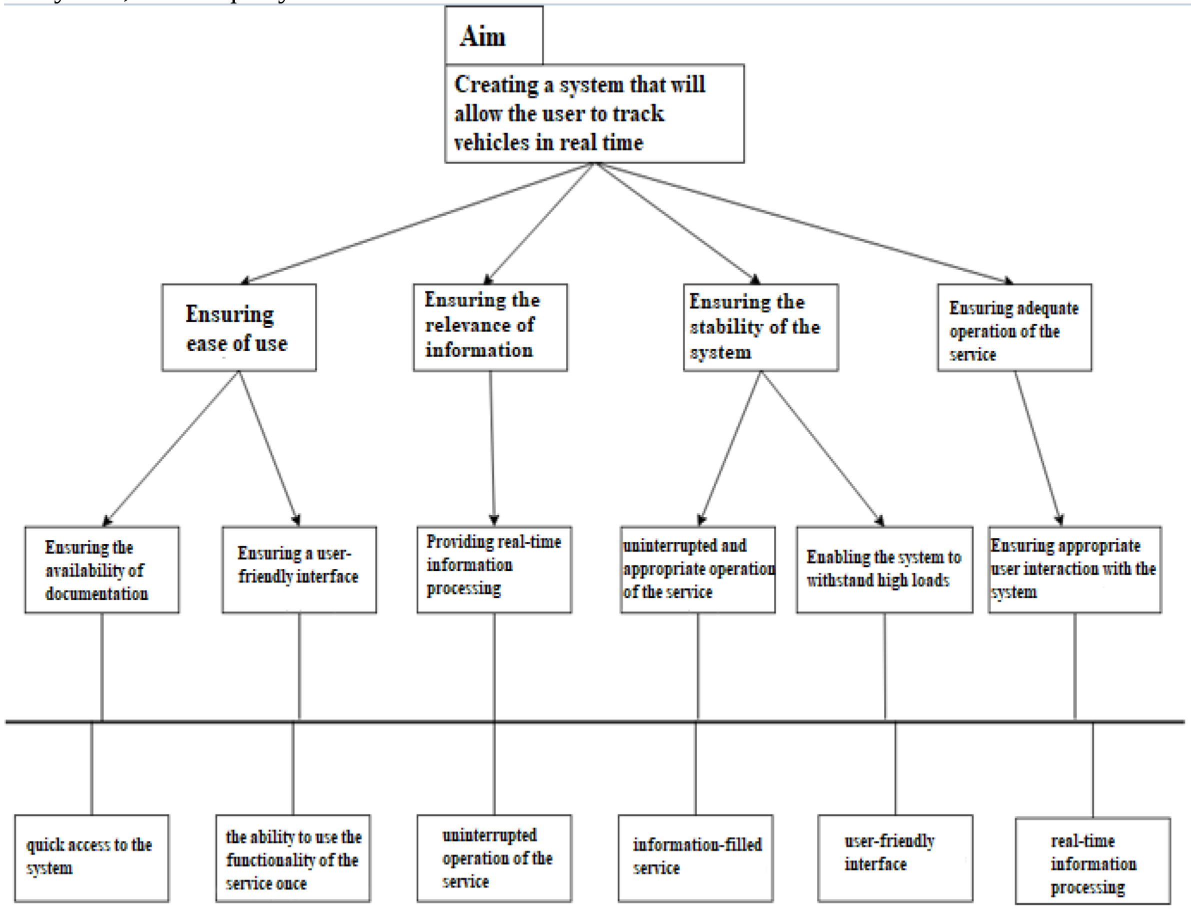

Aim
Creating a system that will allow the user to track vehicles in real time
Ensuring ease of use
Ensuring the relevance of information
Ensuring the stability of the system
Ensuring adequate operation of the service
Ensuring the availability of documentation
Ensuring a user-friendly interface
Providing real-time information processing
uninterrupted and appropriate operation of the service
Enabling the system to withstand high loads
Ensuring appropriate user interaction with the system
quick access to the system
the ability to use the functionality of the service once
uninterrupted operation of the service
information-filled service
user-friendly interface
real-time information processing

Figure 6: System goal tree

The purpose of information relevance is to provide the service with relevant information and providing the possibility of its processing in real-time. The service must be filled with information and “trained” to give the user an appropriate result.

Therefore, according to the criteria, the system can have such types as in Fig. 7.

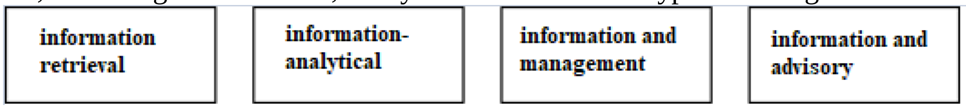


Figure 7: Types of information systems according to criteria

According to the tree of goals built, the primary purpose of the developed system is “Building an intelligent information system for tracking vehicles in real-time”. It is the root of the chart and is decomposed into three sub-goals: “Event Broadcast Platform”, “Information Flow Processing”, and “Data Broadcast”. The first goal, which is to create an event broadcasting platform, consists of sub-goals such as “Configuring the event broadcasting platform” and “Input processing”. Thanks to the event broadcasting platform, the productivity of the service will be high enough to enable users to receive up-to-date information. The next goal in building an asset management system is “Information Flow Processing”. It has the following sub-objectives: “Extracting information”, “Designing a database for easy expansion”, and “Choosing the optimal way to store the state of the system”. This task will create the ability to process all information coming into the system. The productivity of this functionality will increase many times, allowing users to get relevant information without wasting time.

The third and last sub-goal is “Data Broadcasting,” which finds the right ways to display the data coming into the system. To achieve it, you must perform the following tasks: “Continuous supply of data to the client part” and “Timely update of the displayed data”. This goal allows you to visualise all the data. Based on the construction of the goal tree for the developed system, the following quality criteria are defined: stability, easement, the relevance of data, productivity, and scalability.

When studying any system, it is advisable to determine its type by the requirements and quality criteria. The method of analytic hierarchy process (AHP) was used for this purpose. When using it, a matrix of comparisons of the obtained standards is constructed. The results are given in Table 2.

Table 2
Matrix of pairwise comparisons of criteria

No	Criteria	1	2	3	4	5	Rating	Vector priorities
1	Stability	1	2	0.33	0.5	3	1.37	0.19
2	Easement	1	1	0.33	2	2	1.27	0.17
3	Relevance of Data	3	3	1	1	0.5	1.7	0.23
4	Productivity	2	0.5	1	2	3	1.7	0.23
5	Scalability	0.33	2	2	0.33	1	1.32	0.18

Matrices of pairwise comparisons according to each quality criterion for estimation of types of information systems are constructed. The comparison data are given in Table 3.

Table 3
Matrices of pairwise comparisons

No	Stability	1	2	3	4	Rating	Vector priorities
1	Information retrieval	1	0.5	0.5	2	1.0	0.2
2	Information and analytical	2	1	0.33	2	1.33	0.27
3	Information and management	2	3	1	2	2.0	0.4
4	Information and advisory	0.5	0.5	0.5	1	0.63	0.13
No	Easement	1	2	3	4	Rating	Vector priorities
1	Information retrieval	1	0.5	2	2	1.37	0.35
2	Information and analytical	2	1	0.5	1	0.9	0.23
3	Information and management	0.5	2	1	2	0.9	0.23

4	Information and advisory	0.5	1	0.5	1	0.75	0.19
No	Relevance of data	1	2	3	4	Rating	Vector priorities
1	Information retrieval	1	2	3	1	1.75	0.36
2	Information and analytical	0.5	1	0.5	2	1.0	0.2
3	Information and management	0.33	2	1	2	1.33	0.28
4	Information and advisory	1	0.5	0.5	1	0.75	0.16
No	Productivity	1	2	3	4	Rating	Vector priorities
1	Information retrieval	1	1	3	1	1.5	0.29
2	Information and analytical	1	1	0.5	3	1.38	0.27
3	Information and management	0.33	2	1	0.33	0.91	0.18
4	Information and advisory	1	0.33	3	1	1.33	0.26
No	Scalability	1	2	3	4	Rating	Vector priorities
1	Information retrieval	1	0.5	1	0.5	0.75	0.18
2	Information and analytical	2	1	2	3	1.5	0.36
3	Information and management	1	0.5	1	2	0.88	0.22
4	Information and advisory	2	0.33	0.5	1	0.96	0.23

To calculate the final result and priorities by the quality criteria and determine the type of information system, a hierarchical synthesis of alternatives with the help of AHP. The results are shown below.

$$\begin{pmatrix} 0,2 & 0,35 & 0,36 & 0,29 & 0,18 \\ 0,27 & 0,23 & 0,2 & 0,27 & 0,36 \\ 0,4 & 0,23 & 0,28 & 0,18 & 0,22 \\ 0,13 & 0,19 & 0,16 & 0,26 & 0,23 \end{pmatrix} \begin{pmatrix} 0,19 \\ 0,17 \\ 0,23 \\ 0,23 \\ 0,18 \end{pmatrix} = \begin{pmatrix} \mathbf{0,28} \\ 0,263 \\ 0,26 \\ 0,2 \end{pmatrix}$$

According to the final results of applying the method of analysis of hierarchies, it was determined that the type of system for tracking vehicles in real-time - information retrieval system. This type has the highest priority, equal to 0.28, but the indicator is very close to the information-analytical and information-management types based NLP methods [39-43]. After determining the type of information system, it is advisable to build its abstract structure using a hierarchy of tasks, each of which can be performed in parallel or sequentially at the same level of construction. To successfully close the study, you must wait for all its subtasks. Due to this, the developed system is better perceived because the composition of tasks allows you to understand the information better.

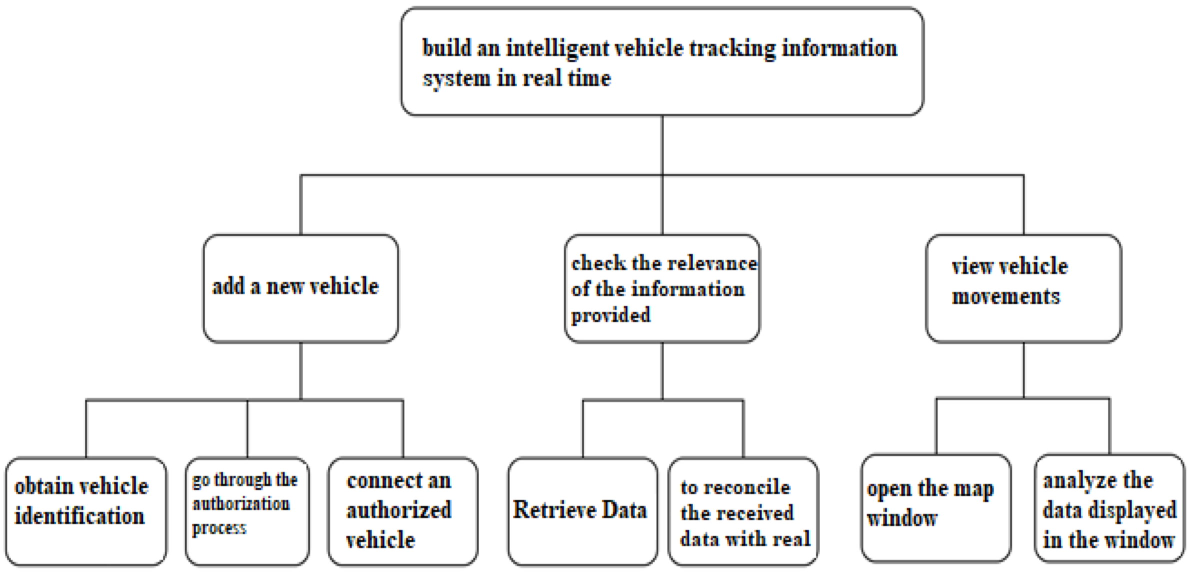

build an intelligent vehicle tracking information system in real time
add a new vehicle
check the relevance of the information provided
view vehicle movements
obtain vehicle identification
go through the authorization process
connect an authorized vehicle
Retrieve Data
to reconcile the received data with real
open the map window
analyze the data displayed in the window

Figure 8: Hierarchy of tasks for the system

3.2. Statement and substantiation of the problem

3.2.1. The purpose of development

To solve any problem, it is necessary to define the main task, goals and form goals. All this includes the primary purpose, definition of terms, clients, customers, the market, corresponding target systems and the subjects responsible for the decision.

The main goal of the developed software is to build a web application and software interface that can be used to track vehicles in real-time. The main tasks and functions of the system include:

- Addition, modification and removal of vehicles;
- Creation of events and the possibility of their processing;
- Possibility of integration with third-party services;
- Providing up-to-date information;
- Localisation;
- Database design and construction.

The system allows you to collect data from all GPS sensors that have access to its services and allows you to automate the fundamental processes involved in monitoring and collecting data on vehicles in the fleet of a particular business. As a result, such solutions have the opportunity to save on transportation costs significantly. On the other hand, if savings are not possible - the system can provide greater convenience for doing business in certain areas. The best approaches have been used to facilitate the display of information and the scalability of the system. The built-in platform for broadcasting events allows you to process large amounts of input data and withstand high loads, allowing the system to work in almost real-time and always provide the user with up-to-date information. The intelligent real-time vehicle tracking information system is modelled by a systems analysis approach and should be built using a “client-server” architecture. In the future, all existing services will be transferred to cloud storage to use a network of remote servers hosted on the Internet for storage, management and data processing. At the moment, it is envisaged that all processes and services will work locally.

3.2.2. The system purpose description

Automation of the main processes and improvement of the user’s interaction and the business with the fleet management system is the primary purpose of the developed product. Mechanical work, mathematical calculations, data translation, data conversion from one type to another are among the tasks of the software. The service is intended for use by both individual users and businesses. Due to the planned scaling, the system can expand in parallel with how a particular enterprise grows.

3.2.3. Place of application of the system

An intelligent real-time vehicle tracking information system provides for its application in many areas - from fleet control for long-distance transportation to delivery of goods. The user of this system can be a user or group of users, small or medium business and large enterprises. The system can be used if its customised version suits the needs of a particular entity. The fact that the design withstands high loads and works in real-time gives it an advantage over analogue systems. The online SaaS service only requires access to the global Internet and pre-registration and authorisation.

3.2.4. Substantiation, development and implementation of the system

Modern vehicle tracking solutions are easy to use and entirely accurate. However, the improvement of such systems also changes the preferences and desires of users of these services - they become more demanding on the characteristics and functionality of the system, its features, prices and more. This situation creates high competition and begins to require more and more research and development costs. Problems of development and lack of resources are also present in vehicle tracking systems.

In this case, the advantage is given to the service that is the most flexible among analogues. Most companies that have released similar products have already built their activities according to classical mass production.

Fleet management is a non-trivial and complex process and requires training in geo-data management and the development of sustainable services. It is almost impossible to perform these processes manually. They are usually slow and complicated, especially if you have many vehicles on your property, so automation does not save consumers as much money as their time. Almost all managers and employees of such departments involve additional software and hardware to solve this problem. Usually, specialists have a sufficient understanding of such systems and are happy to cope with them. Thus, the work solves the main problems of fleet management with the involvement of available third-party services, which is to increase the number of users and products on the market, improve the quality and optimisation of fundamental processes, and integrate related systems.

3.2.5. Expected effects from the implementation of the system

During the analysis of the developed method for automation and optimisation of general processes during vehicle tracking, costs, and other mechanical work, the expected effects of this product's implementation were determined. After that, a scale was developed for their evaluation. Such effects include:

- Functional - is to automate the processes associated with the monitoring of the fleet;
- Financial - increase in investment income from intermediaries and stakeholders and increase in the number of system users, the connection of payment systems;
- Economic is the information system that provides reduction of expenses for the management of vehicles;
- Technological - improvement of conditions of tracking of vehicles and development of new approaches for this purpose;
- Time - because all information is submitted and processed in real-time, this effect involves saving such an essential resource as time;
- Grocery - increase in the number of vehicle tracking devices;
- Public - is the relationship between developers, third-party services and users of the system;
- Communication - advertising of third-party resources with which there is integration.

3.3. A conceptual system model development

The conceptual model makes it possible to formally present the input and output data of the information system at an understandable level and design the data warehouse's logical structure. It includes the definition of tasks, goals, objects, and relationships, which are abstract concepts and allow to generalise the requirements of the developed system. During the infographic conceptual design and modelling of information systems (IS), distinguish the following two methods:

- Descending - a method by which entities are formulated and analysed.
- Ascending is a method that allows you to synthesise the attributes of objects and entities.

In practice, descending design is often used, which identifies and models the logical structure when using a general ER diagram. However, before presenting an abstract model of a financial asset management system, it makes sense to conduct research and identify data that comes directly from the environment and consists of interconnected and original entities.

The result of any system is the initial data that users and administrators can obtain. They are used to track vehicles and are publicly available. It includes:

- The object of the car - all the attributes inherent in the source of its formation;
- A list of all vehicles of a specific company;
- Current positions of all vehicles;
- Data object for integration with third-party services;
- Information objects that are sent in the form of notifications when certain conditions of events are met;

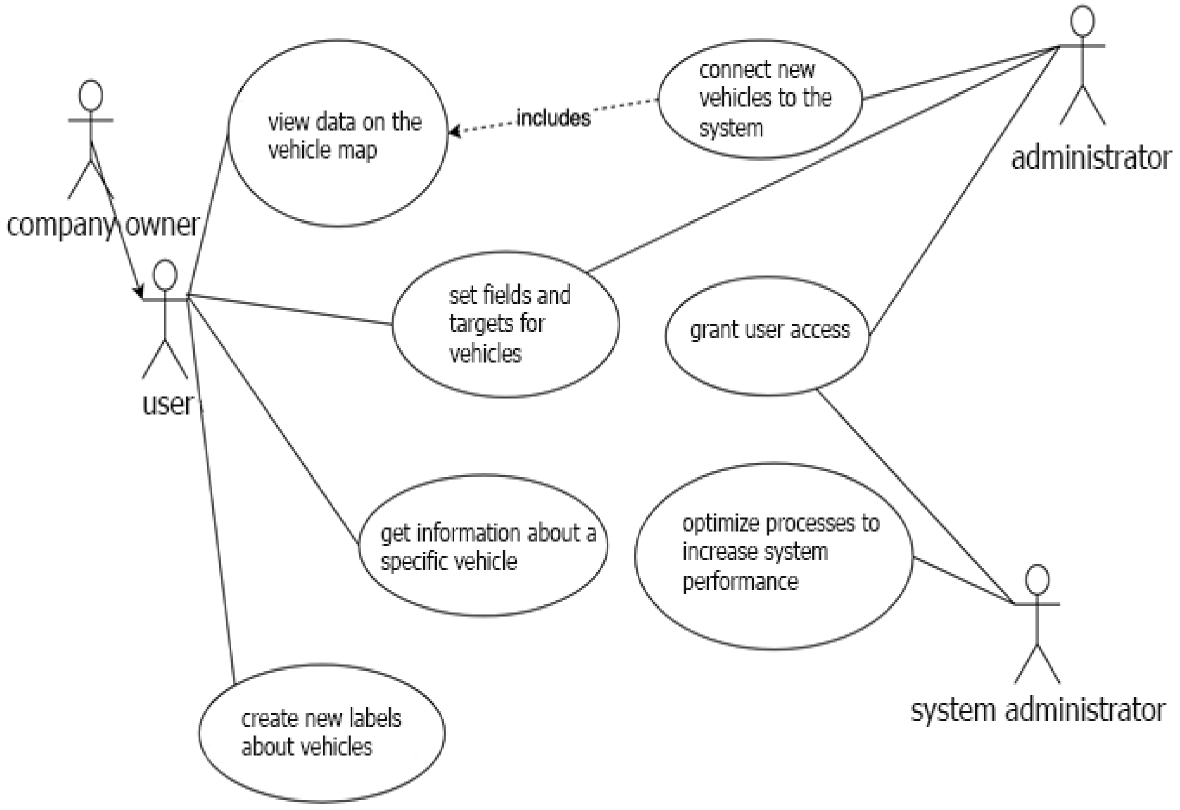
- The current state of the map showing the objects;
- Information about the user, where there is information about his data and company;

3.3.1. Diagram of usage options

The main external entities of the system include:

- **User** is the leading participant in the interaction with the IP, which can use its capabilities and motivate it to take action;
- **The administrator** is the person who is responsible for updating the system and has access to most data.

Critical uses include: view vehicle map, create new vehicle labels, connect new ones to the system, add and grant a user or company access, set fields and targets for vehicles, optimise processes to improve system performance, and more. This type of diagram is given in Fig. 9.



company owner
user
view data on the vehicle map
includes
connect new vehicles to the system
administrator
set fields and targets for vehicles
grant user access
get information about a specific vehicle
optimize processes to increase system performance
create new labels about vehicles
system administrator

Figure 9: Diagram of usage options

In the diagram of the system of analysis of structural and logical schemes of educational programs, there are the following actors: User, Administrator and System Administrator. The “user” will view all the information entered into the system using a graphical interface. The “administrator” generates general information - provides users with access to the design, and connects new vehicles. Finally, the System Administrator is responsible for the system infrastructure.

3.3.2. Class diagram

A UML class diagram is a graphical notation used to build and visualise object-oriented systems. The primary relationships between classes include the relationship of association (relationship between two classes), the relationship of generalisation (inheritance between classes), the relationship of aggregation (one class is an attribute type in another; partial case of the relationship of association) and the relationship of composition (existence of one class is impossible without “Father”, where it is used). The class diagram of the developed system is given in Fig. 10.

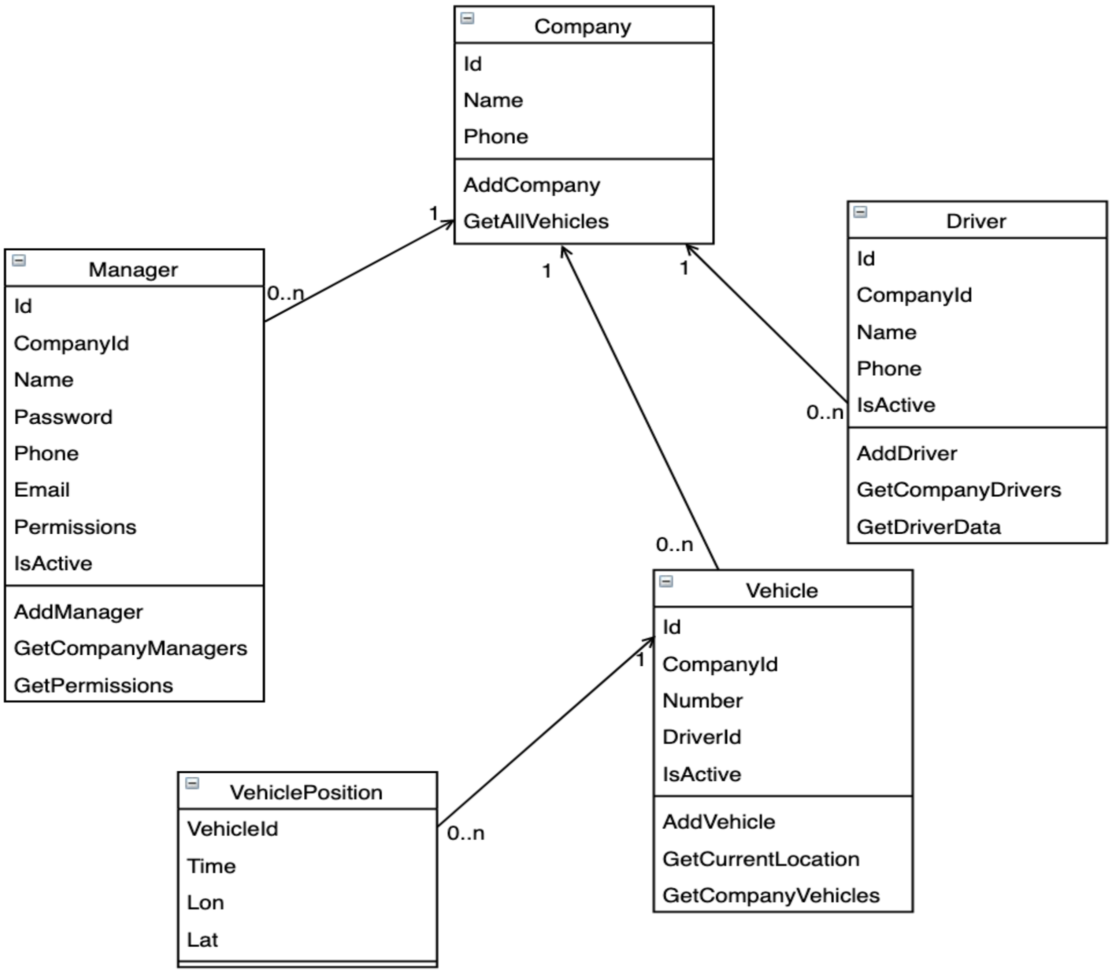


Figure 10: Class diagram

The constructed diagram consists of the following primary classes, each of which has several attributes that do not require further explanation, and methods:

- *Company*- a class for depicting the basic properties and behaviour of the company. It consists of several attributes and operations that are designed to keep track of existing companies in the system;
- *Manager*- a class that describes the properties and characteristics of the essence of the manager. Manager authentication and authorisation are the main methods;
- *Driver*- class to describe the essence of the driver. The main methods are to obtain information about a particular driver and his connection with vehicles;
- *Vehicle* -introductory class describing the car. This entity includes data related to operations on vehicles and their characteristics;
- *VehiclePosition* is a class to describe the entity that determines the position of a particular vehicle at a specific point in time, the main task of which is to preserve data about all parts in the past.

3.3.3. State transition diagram

In UML, the state diagram is used to describe the sequences of states and transitions during the life cycle of the developed system. Simulation of changes in the states of objects is the basis for modelling this type of diagrams. A state is the place of an object in his life at a particular point in time when he is waiting or taking action. The initial state is when the object is in it from the very beginning of the operation. This type of state is unique, which still contains the final. Individual states, in particular the initial one, have no actions that can occur internally. The diagram is given in Fig. 11.

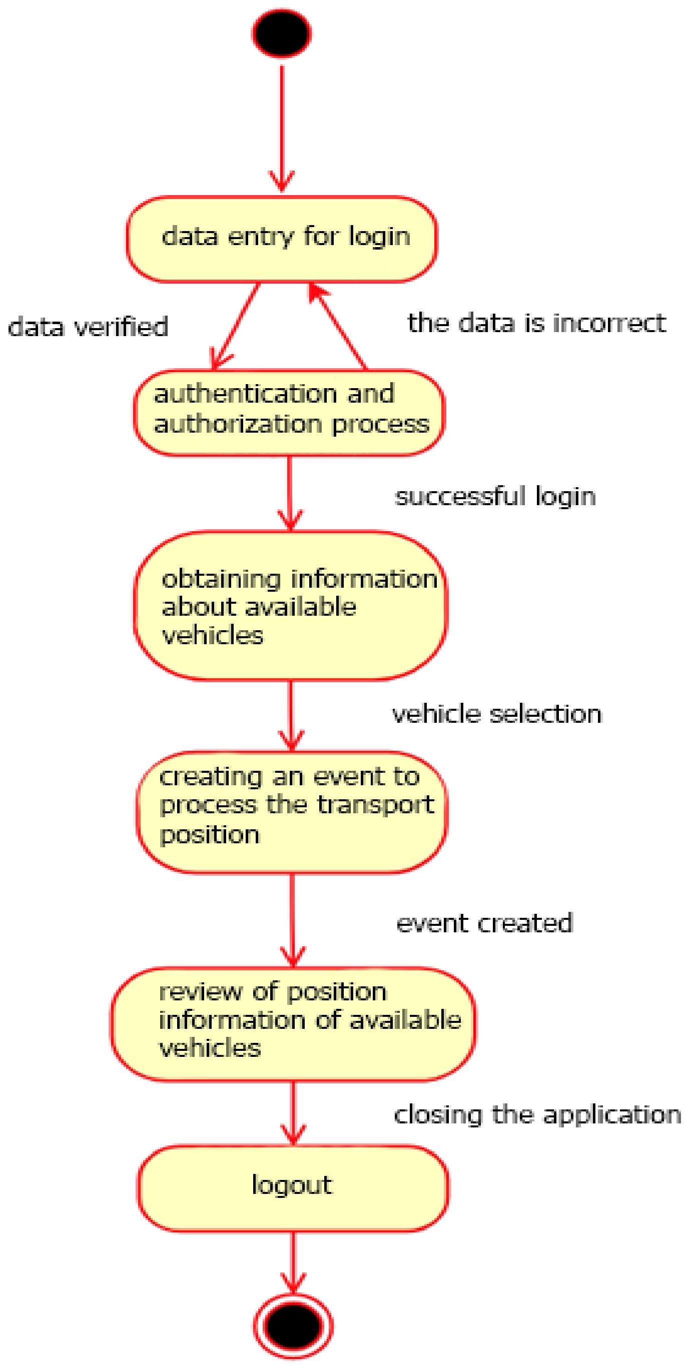

data entry for login
data verified
the data is incorrect
authentication and authorization process
successful login
obtaining information about available vehicles
vehicle selection
creating an event to process the transport position
event created
review of position information of available vehicles
closing the application
logout

Figure 11: State transition diagram

The state in which the user fills in all the necessary data for authorisation in the system is considered initial in this process. If there are specific errors to check the correctness, the user does not go to the next state. Instead, when you log in, you go to the state of the main page, i.e. the overview map, which shows all available vehicles. The user can select any available vehicle to obtain additional information about it or create a specific event related to achieving the transport of a particular position. To log out, click "Log Out". After that, there is a transition to the final state, which indicates the end of the process.

3.3.4. Activity chart

For the developed system, the diagram of activity is given in Fig. 12.

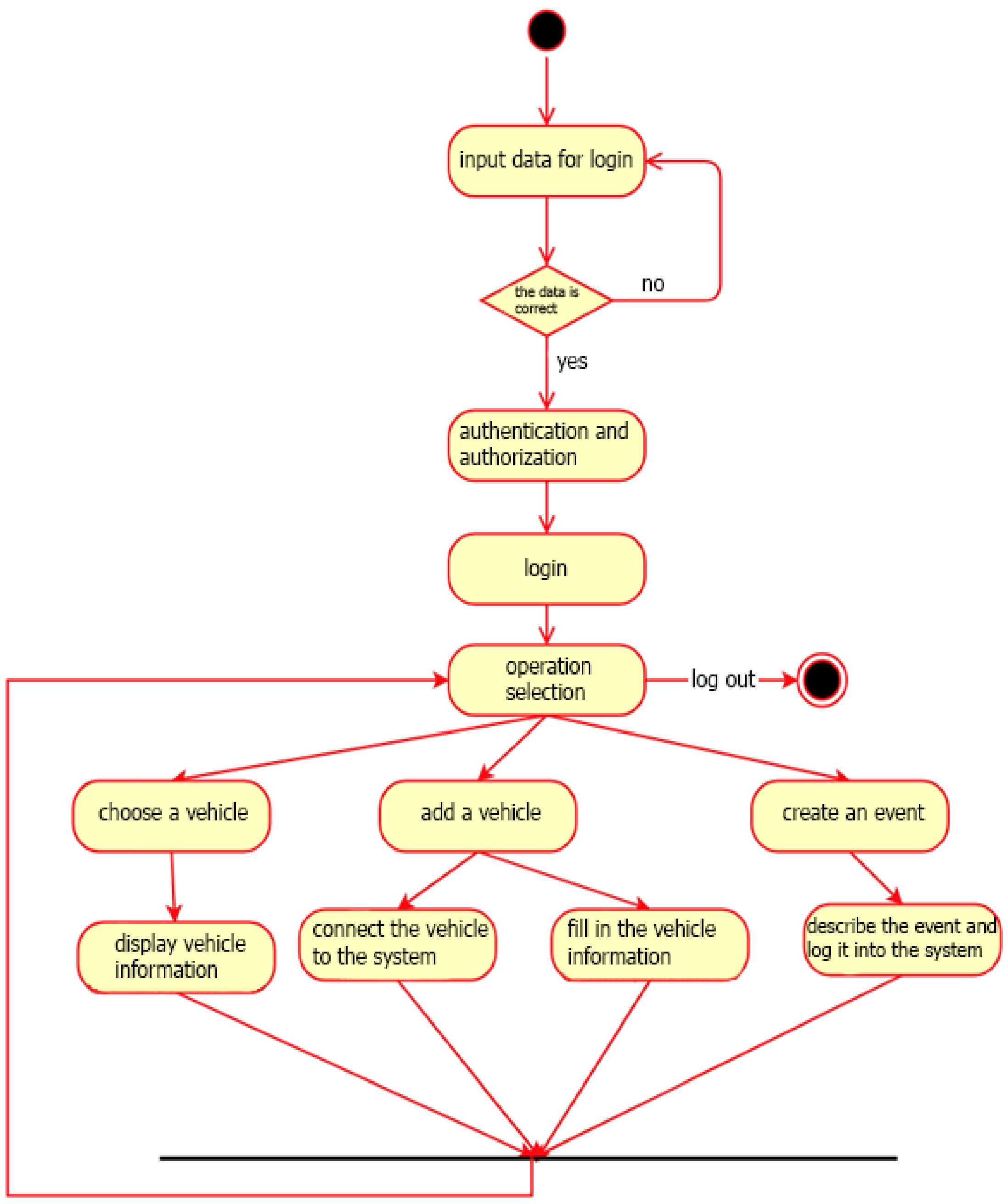

input data for login
the data is correct
no
yes
authentication and authorization
login
operation selection
log out
choose a vehicle
add a vehicle
create an event
display vehicle information
connect the vehicle to the system
fill in the vehicle information
describe the event and log it into the system

Figure 12: Activity chart

The initial state of the system is the input of the necessary input information. If the data transfer is successful, the user is authenticated and authorised. If any errors occur during user login, the user returns to the login form until the data is correct. After the user logs in, the system logs in and proceeds to the activity, which involves selecting the following operations. The list of activities of choice includes:

- Activity “Select vehicle” allows you to get all the additional information about a particular vehicle. After switching to the activity “Display information about the vehicle”, the user can go to the final state or return to the activity “Operation selection”;
- The activity “Add a vehicle” allows to perform such works as “Connect the vehicle to the system” or “Fill in the information about the vehicle”, after their selection and implementation, the transition to the form of activity selection or the final state of the system;
- The “Create event” activity also means that the user can “Describe the event and enter into the system” activity. It will be able to return to the menu of operations or end the work with the system.

3.3.5. Sequence diagram

A sequence diagram has been constructed for the Add Vehicle option. During this interaction process, the following objects:

- User - an object that is the initiator of all manipulations on the system and can use its functions;
- System - the main link of the studied precedent, which is responsible for processing input and output information and calling functions;
- Database - a place where information is stored.

The sequence diagram is given in Fig. 13.

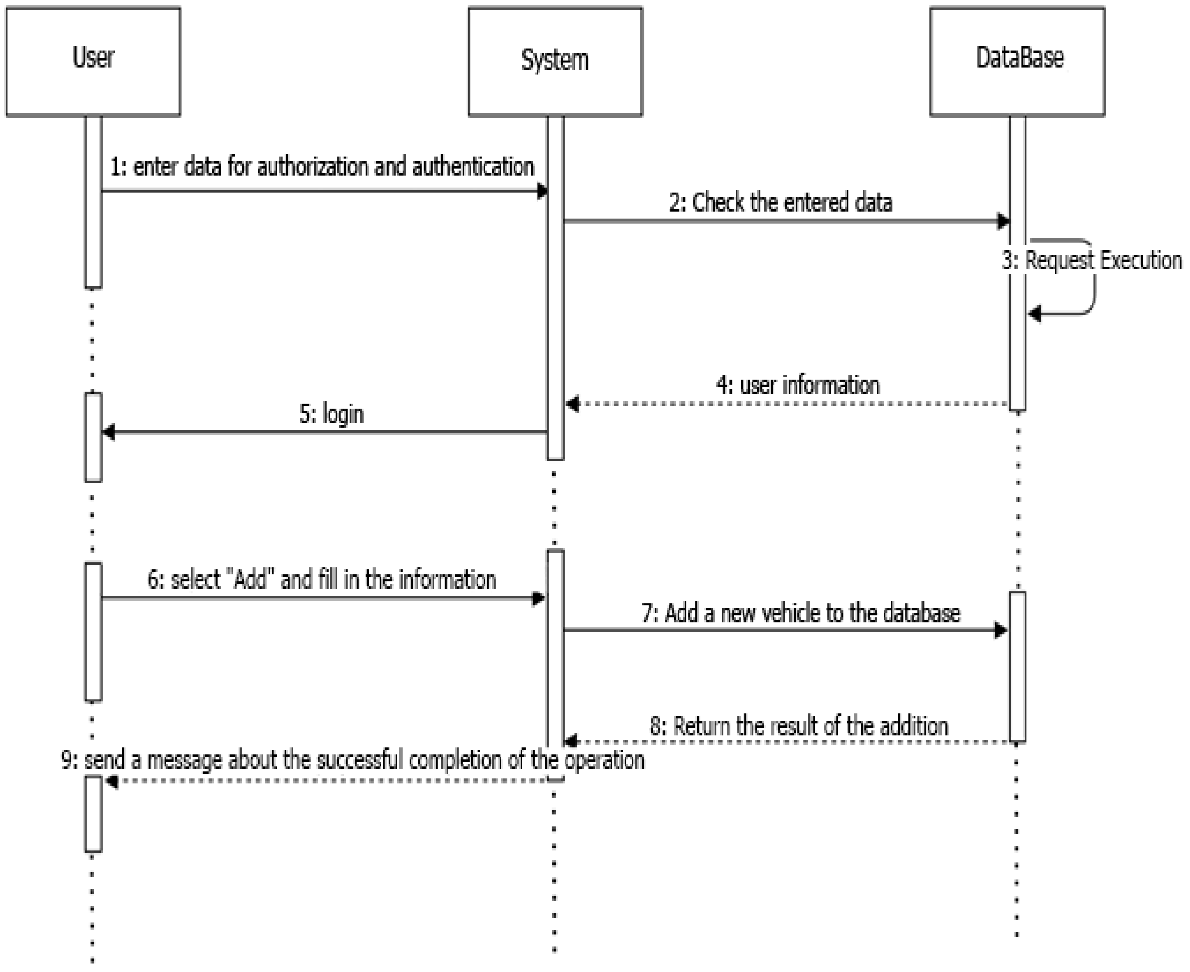

User
System
DataBase
1: enter data for authorization and authentication
2: Check the entered data
3: Request Execution
4: user information
5: login
6: select "Add" and fill in the information
7: Add a new vehicle to the database
8: Return the result of the addition
9: send a message about the successful completion of the operation

Figure 13: Sequence diagram

To add a new vehicle, the user must first log in and authenticate to the system. Then, if he has the necessary rights, he can initiate a new car using the appropriate command in the menu. As soon as the user fills in all the information about the object, a request is made to the system. In case of entering the correct information, this data is entered into the database, and the method returns a message about the successful completion of the operation.

3.3.6. Component diagram

The component scheme divides the existing system being developed into various high levels of functionality. Each component is responsible for one straightforward goal throughout the design and interacts with other essential elements that it needs to know. Accordingly, the main features such as React.js, SpringBootApplication and the database were selected to present the software modules of the financial asset management system. The diagram of parts is given in Fig. 14.

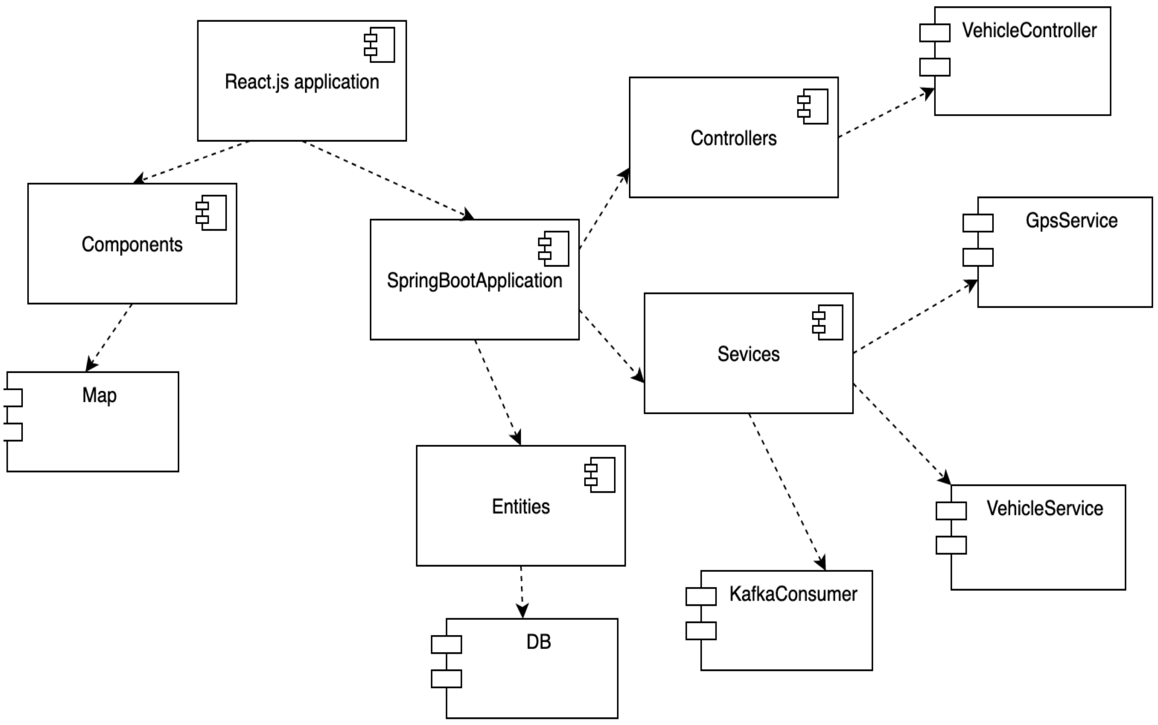


Figure 14: Component diagram

The SpringBootApplication file is the main entry point and core of the real-time vehicle tracking system. This component is the REST API, which accepts requests from the client-side. This component consists of Entities, Services and Controllers packages. The Services package is responsible for all business logic of the program and is the main functionality. Controllers, in turn, ensures the operation of the application interface for communication between the server and clients. Entities package using the principle of ORM, i.e. technology for communication between database and system objects. Examples of server files are SpringBootApplication, VehicleService, KafkaConsumer, GpsService, VehicleController and more. The component responsible for the client part is called React.js application, which aims to communicate with the server using the REST API and display data to the user. An example of the files in this component is map. The main entry points are SpringBootApplication and React.js application.

In the second section of the work, during a systematic approach to the analysis of intelligent information system for vehicle tracking in real-time, its type is determined - information retrieval in Smart City [44-49]. It is done using the method of calculation of hierarchies after the analysis of system criteria. During the work, a tree of goals was built, a conceptual model was developed, as a result of which the following types of diagrams were made: use cases, classes, sequences, state transitions, activity. Each of them is described and as detailed as possible. The system is now detailed, and its processes are described.

3.4. Software tools for solving the problem

The main goal of the developed system was to provide the user with information about the vehicle, its position, characteristics and condition in real-time in a convenient way, using the methods of streaming events. So, the main issues to solve the problems were method:

- Data delivery and visualisation;
- Reliable and fast data transfer between the service and objects;
- The client and server interact.

Method of data delivery and visualisation:

- The system is offered to the user in the form of a web application that can be opened in a web browser;
- All data on available vehicles of the current user are entered into the system database;
- System services communicate with each other, send a request, perform aggregation, and send the result to the client part.

Method of reliable and fast data transfer between service and objects:

- The system receives data from vehicles and enters them into the service that is responsible for the flow of events (event streaming);
- The system receives data from the flow of events and updates the status of all available vehicles;
- The web client receives the current information using the REST API, sending requests once in a certain period.

How the client and server interact:

- The server part implements the REST software interface, which the client can access at any time to obtain up-to-date information;
- Using the API, the system receives messages and sends the necessary data to the next step;
- The system gets the processing result and shows the user the updated data.

Having described the main issues for solving system implementation problems, you can start choosing technologies for development.

3.5. Technical characteristics of selected software development tools

Before starting work on the project, the programming language used on the server part fell to Node.js, C # or Java [50-51]. To finally determine, a comparative table was created.

Table 4
Comparison of programming languages or project development environments

Characteristic Language	Java	Node.js	C #
Type	Object-oriented, class-based	Runtime library, cross-platform environment for creating JS applications outside the browser	Object-oriented, component-oriented, strongly typed
Execution time	Java Runtime Environment	Chrome`s V8 JavaScript engine	Common Language Runtime
Project size	Complex, large projects	Small projects	Complex, large projects
Scope	Interaction with the server part prevails	Interaction with client and server parts	Web or game applications
Popularity	Very high	High	High

After the comparison, the choice fell on the Java programming language due to its popularity and knowledge. Also, the reasons include the ability to scale the program to increase functionality or the number of users.

Notable features of Spring Boot:

- Automatic configuration: customise your program based on the environment and notifies the developers;
- Autonomy: literally, it is entirely autonomous. Therefore, there is no need to deploy your program on a web server or in a unique environment. The only task is to press the button or issue the run command, and it will start;
- Automatic configuration tries to automatically configure the program based on the dependencies that have been added. The framework is contextually aware and intelligent.

MySQL is open-source relational database management system based on structured query language (SQL) [54]. Using MySQL Workbench, the developer can design, model, generate and manage databases. The tool has everything you need to model data and create complex ER models, direct and reverse design.

Hibernate is a mapping tool between objects and relational structures (ORM) for the Java platform [55]. Hibernate's goal is to free the developer from the significant typical tasks of database interaction programming. The developer can use Hibernate both when developing from scratch and for an existing database. Hibernate takes care of the so-called 'connection of classes with database tables (and data types of programming language with SQL data types), and provides the means to automatically build SQL queries and read/write data, and can significantly reduce development time, which is usually spent manually writing standard SQL and JDBC code. The mapping informs the ORM tool about which store a Java class object in a database table. This section discusses the main tools and technologies used to write the project. Devices used to develop a web-based real-time vehicle tracking system:

- Programming language on the server part - Java using the Spring framework;
- Client-side programming language - Javascript, React.js library
- Development environment - IntelliJ IDEA;
- Event broadcasting platform - Apache Kafka;
- Database management system - MySQL using visualisation using MySQL Workbench;

4. Experiments, results and discussion

4.1. The created software description

The created software product purpose is to implement a web application [56] as situational awareness system [57-58] or recommendation system [59-64], which will be divided into two parts: client and server. Using the REST API will receive the current data from the server and give the user the desired result. The developed program for real-time vehicle tracking is called VTracker. The system is built based on client-server architecture and relational database.

The program consists of the following three parts:

- User communication with the web application and chatbots [30-35] based on NLP [39-43];
- Communication of the web application with the server part [56-64];
- Contact of devices in vehicles with the server part [1-9].

This program works with only one type of user - the fleet manager of cars. User functionality:

- Connects new vehicles;
- Reviews the position of available vehicles;
- Establishes additional information about vehicles;
- Reviews the characteristics of existing vehicles;
- Creates events and receives notifications about them;
- Obtained result of information analysis based Deep Learning for Statistical Detection Criteria about vehicles characteristics [65-72].

When creating a web application, the interfaces of the program were separated as shown in Fig. 15 and their implementation for further coverage by Unit-tests.

Because the created project is created using the tool for building Gradle, the following Spring libraries were connected: Web, AOP, Data JPA. In addition, auxiliary libraries and utilities have also been added: Apache Kafka, Lombok, slf4j-log4j12, the complete list of which can be seen in Fig. 16.

All information intended for the proper functioning of the information system shall be stored in the data warehouse. A relational MySQL database was used for this purpose. Any database can be presented schematically to logically represent it and describe the data stored there and solve the main problems of the study area. The scheme of data visualisation is given in Fig. 17. The designed database consists of five main entities. Let's describe them. The essence of "Company" is designed to store data about the company that keeps records and its vehicles tracks in the system. Its attributes include:

- id is a unique company key;
- name is the name of the company in the system;
- phone is contact phone.

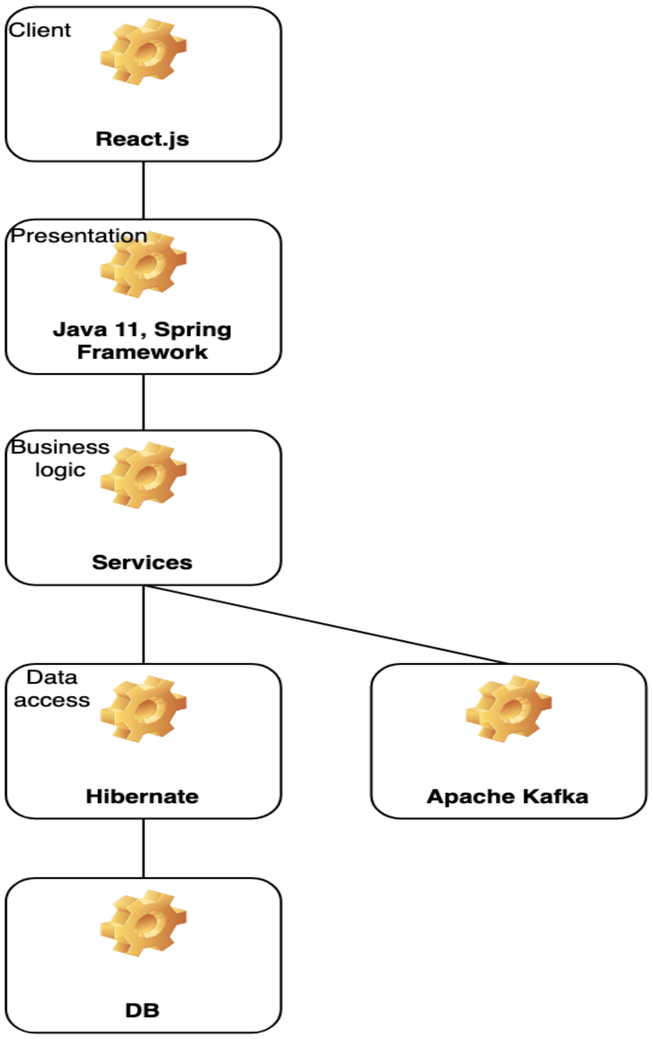
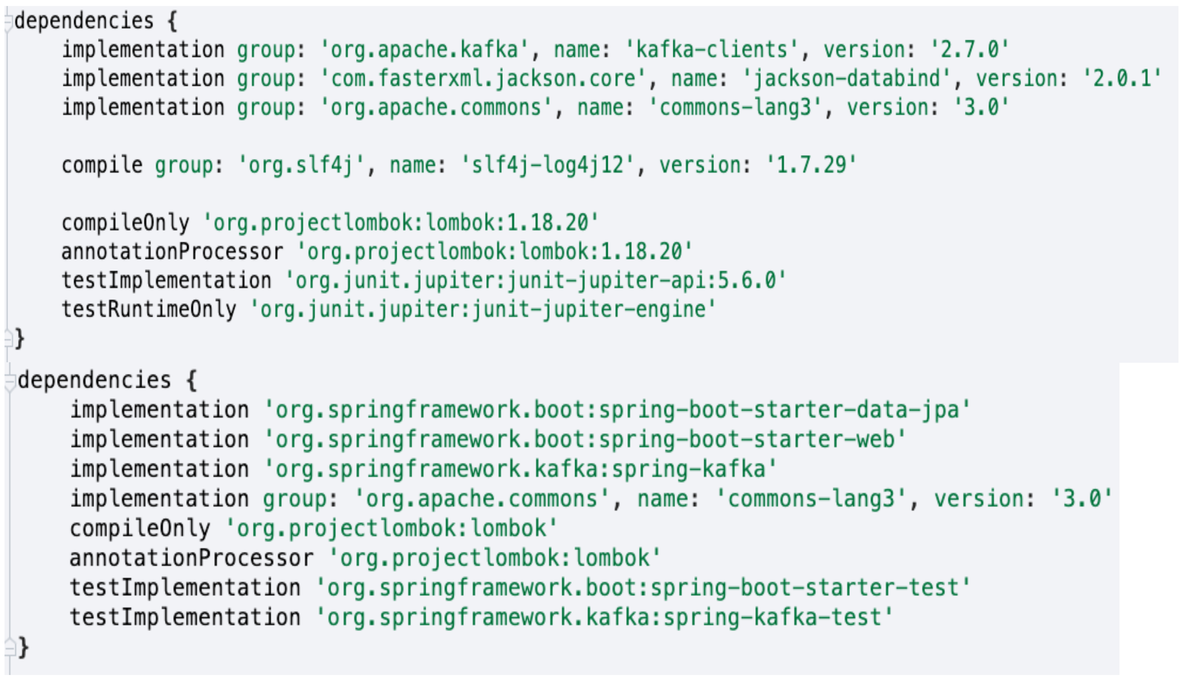


Figure 15: System architecture



```
dependencies {
    implementation group: 'org.apache.kafka', name: 'kafka-clients', version: '2.7.0'
    implementation group: 'com.fasterxml.jackson.core', name: 'jackson-databind', version: '2.0.1'
    implementation group: 'org.apache.commons', name: 'commons-lang3', version: '3.0'

    compile group: 'org.slf4j', name: 'slf4j-log4j12', version: '1.7.29'

    compileOnly 'org.projectlombok:lombok:1.18.20'
    annotationProcessor 'org.projectlombok:lombok:1.18.20'
    testImplementation 'org.junit.jupiter:junit-jupiter-api:5.6.0'
    testRuntimeOnly 'org.junit.jupiter:junit-jupiter-engine'
}
dependencies {
    implementation 'org.springframework.boot:spring-boot-starter-data-jpa'
    implementation 'org.springframework.boot:spring-boot-starter-web'
    implementation 'org.springframework.kafka:spring-kafka'
    implementation group: 'org.apache.commons', name: 'commons-lang3', version: '3.0'
    compileOnly 'org.projectlombok:lombok'
    annotationProcessor 'org.projectlombok:lombok'
    testImplementation 'org.springframework.boot:spring-boot-starter-test'
    testImplementation 'org.springframework.kafka:spring-kafka-test'
}
```

Figure 16: List of dependencies in the build.gradle file

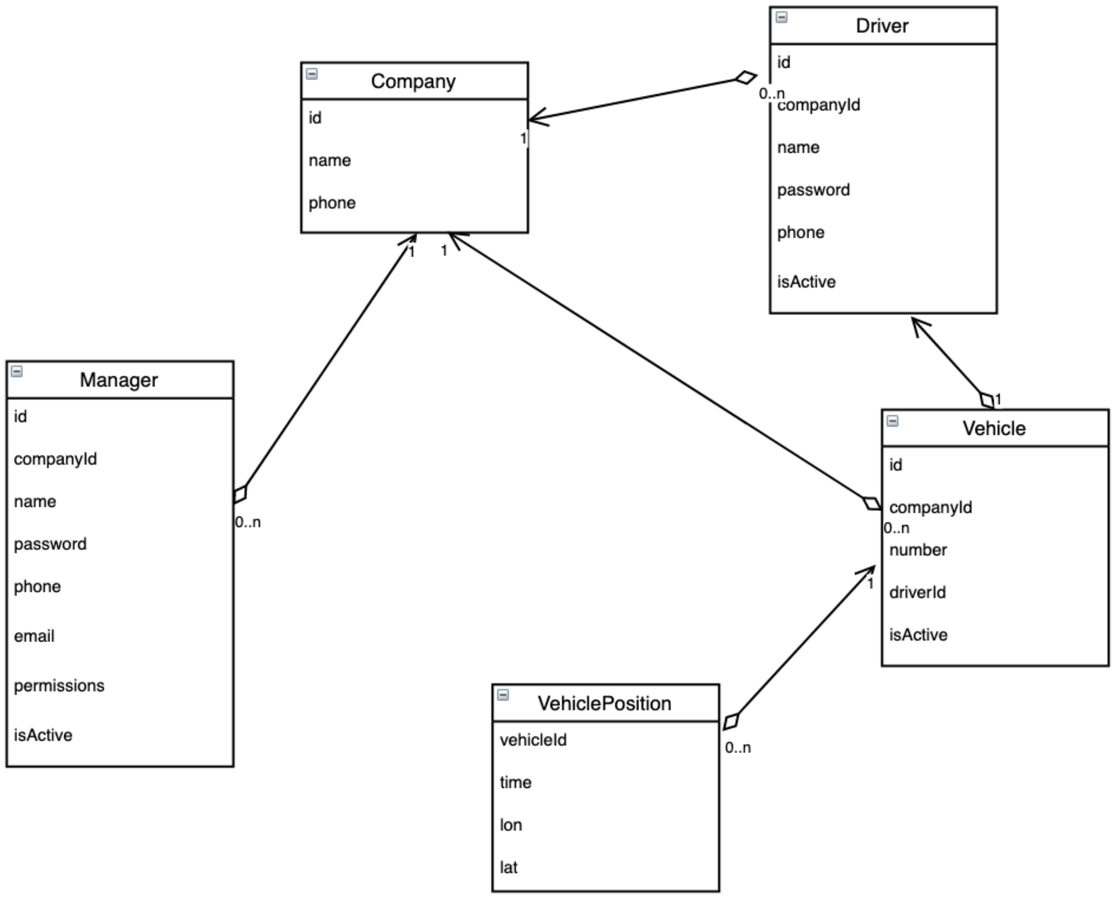


Figure 17: Data visualisation scheme

The essence of “Manager” defines the managers who supervise the company’s vehicles. This entity has a “many-to-one” relationship with the nature of “Company”, its attributes:

- id - unique key of the manager;
- companyId - is key-link to the essence of “Company”;
- name - is the name of the manager in the system;
- password - is the password for logging in;
- phone - is contact phone;
- email - is e-mail;
- permissions - is the list of licenses of the manager;
- isActive - is manager activity identifier.

The Driver entity is designed to store records of all available drivers of all companies in the system. The entity has a many-to-one relationship with the Company entity. Its attributes include:

- id - is unique driver key;
- companyId - is key-link to the essence of “Company”;
- name - is the name of the driver in the system;
- password - is the password for logging in;
- phone - is contact phone;
- isActive - is driver activity identifier.

Essence “Vehicle” allows you to store records of vehicles in the system. This entity has a “many-to-one” relationship with the “Company” entity and a “one-to-one” entity with the “Driver” entity, its attributes:

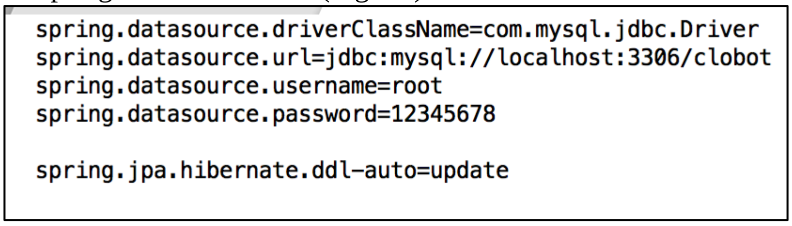
- id - is unique vehicle key;
- companyId - is key-link to the essence of “Company”;
- number - is vehicle number;

- driverId - is key-reference to the nature of “Driver”;
- isActive - is vehicle activity identifier.

The essence of “VehiclePosition” is designed to store the history of the position of all vehicles. It has a “many-to-one” relationship with the nature of “Vehicle “. Its attributes include:

- vehicleId - is key-reference to the essence of “Vehicle”;
- time - is the time at which the vehicle was in this position;
- lon - is longitude;
- lat - is latitude;

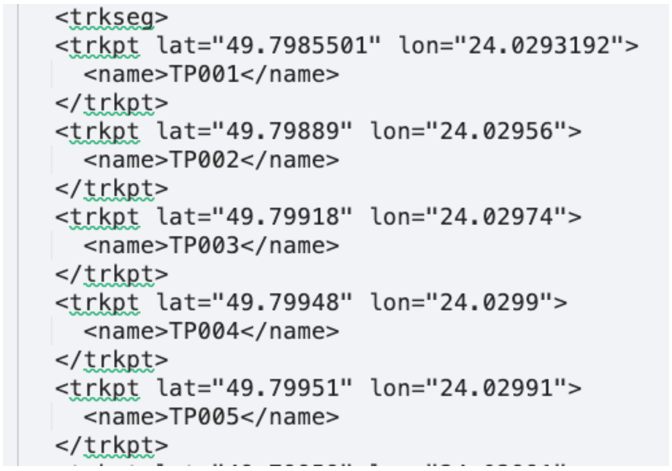
In connection with the connection of the database, it was necessary to describe further the configuration of the Spring Boot framework (Fig. 18)



```
spring.datasource.driverClassName=com.mysql.jdbc.Driver
spring.datasource.url=jdbc:mysql://localhost:3306/clobot
spring.datasource.username=root
spring.datasource.password=12345678

spring.jpa.hibernate.ddl-auto=update
```

Figure 18: Application.properties configuration file

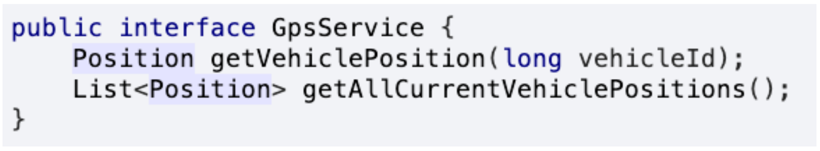
For test use, the program cannot use current vehicles to track their position and status, so it was necessary to develop several .gpx files to further simulate the movement of objects on the map. GPX files could be parsed as an XML file using existing Java libraries, but a ready-made open-source library called geoKarambola was used for development speed. It allows you to extract the necessary objects from a .gpx file without describing the tags that have been used, which significantly speeds up work with files of this type.



```
<trkseg>
<trkpt lat="49.7985501" lon="24.0293192">
  <name>TP001</name>
</trkpt>
<trkpt lat="49.79889" lon="24.02956">
  <name>TP002</name>
</trkpt>
<trkpt lat="49.79918" lon="24.02974">
  <name>TP003</name>
</trkpt>
<trkpt lat="49.79948" lon="24.0299">
  <name>TP004</name>
</trkpt>
<trkpt lat="49.79951" lon="24.02991">
  <name>TP005</name>
</trkpt>
```

Figure 19: Excerpt from a .gpx file

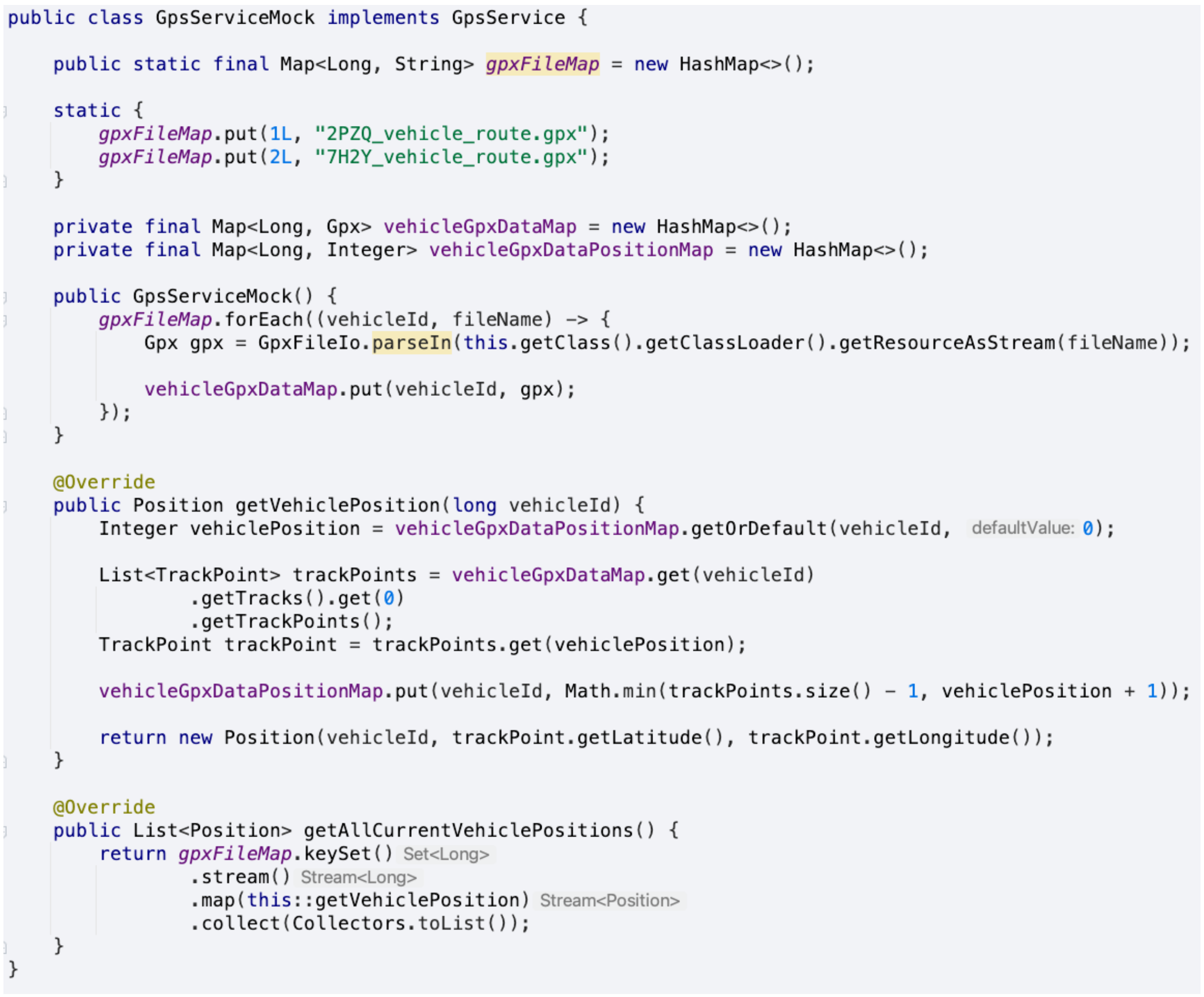
To work on business logic, the GpsService interface was created, which describes the processes that can be performed with geodata (Fig. 20). This interface was designed to represent the functions that should be inherited by a class that will be responsible for working with geodata. As you can see in the figure, two methods were created - to obtain the position of one vehicle by its identifier or the parts of all available cars.



```
public interface GpsService {
    Position getVehiclePosition(long vehicleId);
    List<Position> getAllCurrentVehiclePositions();
}
```

Figure 20: GpsService interface content

To use this service, it is necessary to inherit and implement the described methods. Since test data will be used to test the system, it will be helpful to create a GpsServiceMock class and use all of the above. That is, read the data files in this class and forward them further down the system chain.

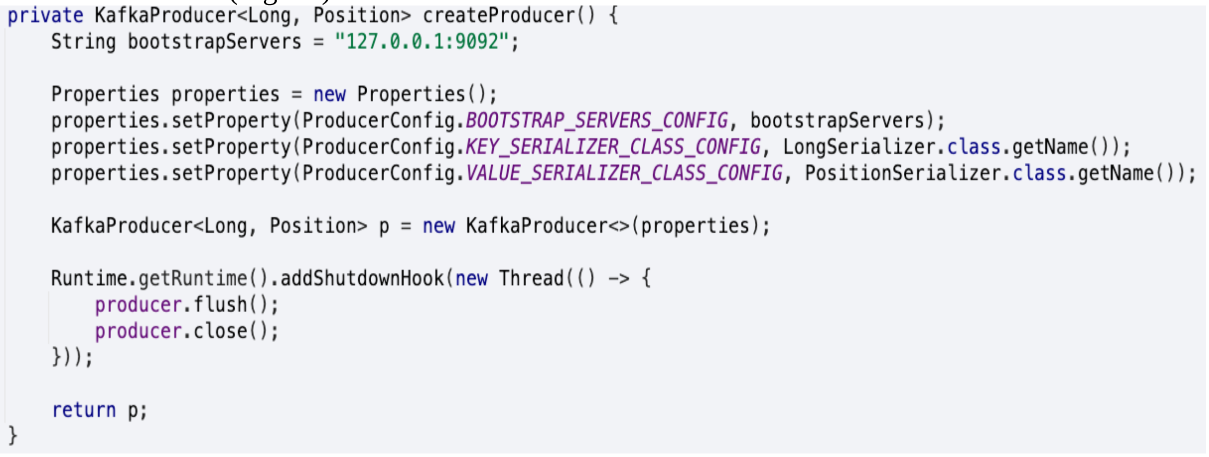


```java
public class GpsServiceMock implements GpsService {

    public static final Map<Long, String> gpxFileMap = new HashMap<>();

    static {
        gpxFileMap.put(1L, "2PZQ_vehicle_route.gpx");
        gpxFileMap.put(2L, "7H2Y_vehicle_route.gpx");
    }

    private final Map<Long, Gpx> vehicleGpxDataMap = new HashMap<>();
    private final Map<Long, Integer> vehicleGpxDataPositionMap = new HashMap<>();

    public GpsServiceMock() {
        gpxFileMap.forEach((vehicleId, fileName) -> {
            Gpx gpx = GpxFileIo.parseIn(this.getClass().getClassLoader().getResourceAsStream(fileName));

            vehicleGpxDataMap.put(vehicleId, gpx);
        });
    }

    @Override
    public Position getVehiclePosition(long vehicleId) {
        Integer vehiclePosition = vehicleGpxDataPositionMap.getOrDefault(vehicleId,  defaultValue: 0);

        List<TrackPoint> trackPoints = vehicleGpxDataMap.get(vehicleId)
                .getTracks().get(0)
                .getTrackPoints();
        TrackPoint trackPoint = trackPoints.get(vehiclePosition);

        vehicleGpxDataPositionMap.put(vehicleId, Math.min(trackPoints.size() - 1, vehiclePosition + 1));

        return new Position(vehicleId, trackPoint.getLatitude(), trackPoint.getLongitude());
    }

    @Override
    public List<Position> getAllCurrentVehiclePositions() {
        return gpxFileMap.keySet() Set<Long>
                .stream() Stream<Long>
                .map(this::getVehiclePosition) Stream<Position>
                .collect(Collectors.toList());
    }
}
```

Figure 21: Contents of the GpsServiceMock class that inherits from GpsService

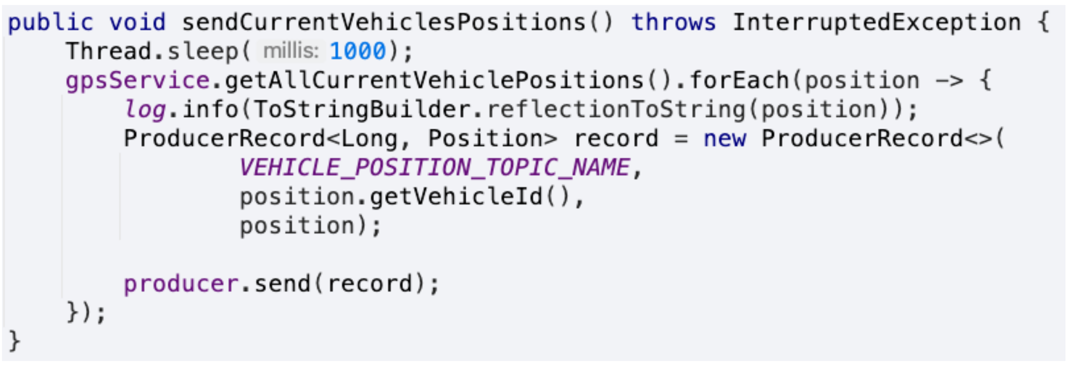
The next step is to transfer data to the Apache Kafka cluster to ensure system resilience to failures and high loads. The data in the collection will be stored for several days, which will allow you to monitor unforeseen situations that occurred earlier. To transfer data to the Apache Kafka cluster, you need to configure Kafka Producer using the library that was added to the project. Described the manufacturer connects to a local cluster that is deployed using Apache Zookeeper, the service on which Apache Kafka runs, to configure its service groups and, in addition, the Kafka server itself.

All services and necessary resources are deployed on the embedded tomcat server, which is built into the framework (Fig. 24).



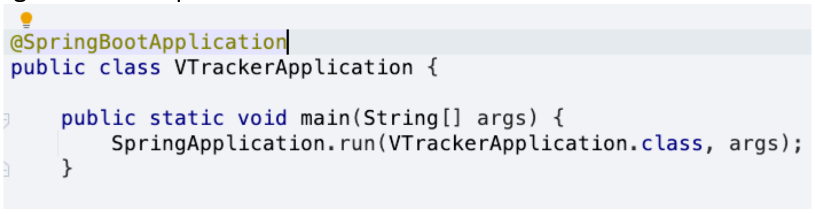
```java
private KafkaProducer<Long, Position> createProducer() {
    String bootstrapServers = "127.0.0.1:9092";

    Properties properties = new Properties();
    properties.setProperty(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG, bootstrapServers);
    properties.setProperty(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG, LongSerializer.class.getName());
    properties.setProperty(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG, PositionSerializer.class.getName());

    KafkaProducer<Long, Position> p = new KafkaProducer<>(properties);

    Runtime.getRuntime().addShutdownHook(new Thread(() -> {
        producer.flush();
        producer.close();
    }));

    return p;
}
```

Figure 22: Creation and configuration of Kafka Producer



```java
public void sendCurrentVehiclesPositions() throws InterruptedException {
    Thread.sleep( millis: 1000);
    gpsService.getAllCurrentVehiclePositions().forEach(position -> {
        log.info(ToStringBuilder.reflectionToString(position));
        ProducerRecord<Long, Position> record = new ProducerRecord<>(
                VEHICLE_POSITION_TOPIC_NAME,
                position.getVehicleId(),
                position);

        producer.send(record);
    });
}
```

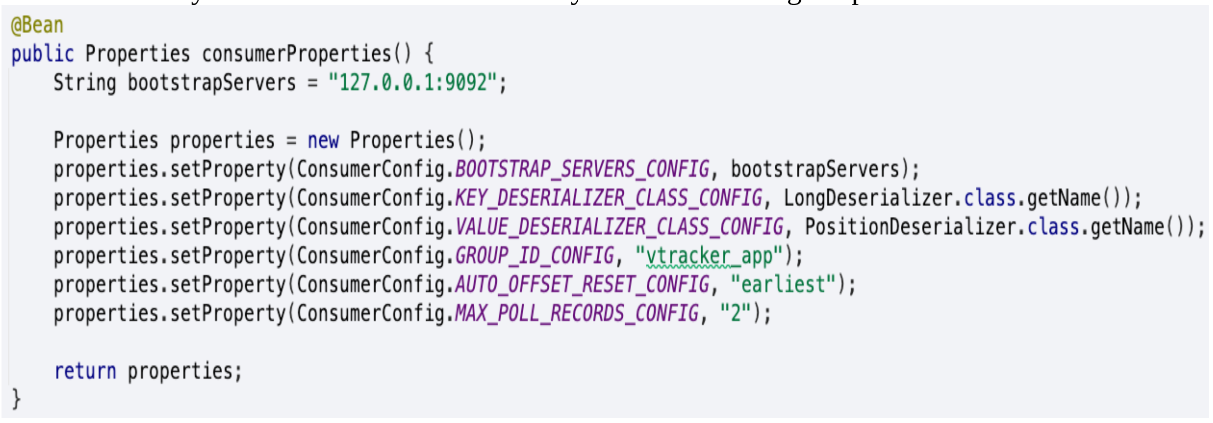
Figure 23: Sending the current positions of all vehicles to the cluster



```java
@SpringBootApplication
public class VTrackerApplication {

    public static void main(String[] args) {
        SpringApplication.run(VTrackerApplication.class, args);
    }
```

Figure 24: VTrackerApplication class with main method

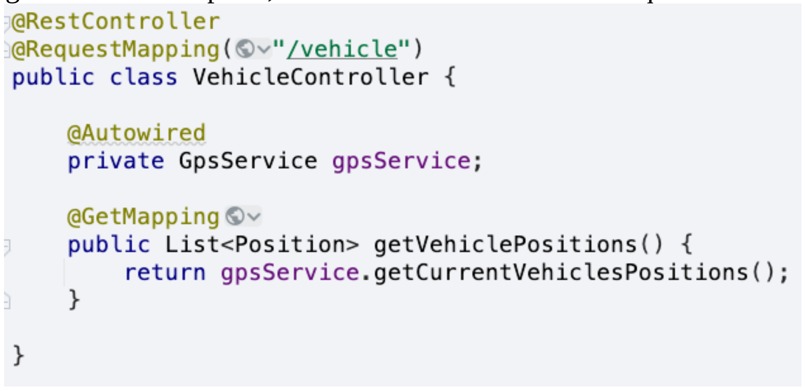
Also, for simplicity, Kafka Consumer's configuration was added to the same class - this is a service that allows the system to receive all the necessary information using the poll method.



```java
@Bean
public Properties consumerProperties() {
    String bootstrapServers = "127.0.0.1:9092";

    Properties properties = new Properties();
    properties.setProperty(ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG, bootstrapServers);
    properties.setProperty(ConsumerConfig.KEY_DESERIALIZER_CLASS_CONFIG, LongDeserializer.class.getName());
    properties.setProperty(ConsumerConfig.VALUE_DESERIALIZER_CLASS_CONFIG, PositionDeserializer.class.getName());
    properties.setProperty(ConsumerConfig.GROUP_ID_CONFIG, "vtracker_app");
    properties.setProperty(ConsumerConfig.AUTO_OFFSET_RESET_CONFIG, "earliest");
    properties.setProperty(ConsumerConfig.MAX_POLL_RECORDS_CONFIG, "2");

    return properties;
}
```

Figure 25: Kafka Consumer configuration

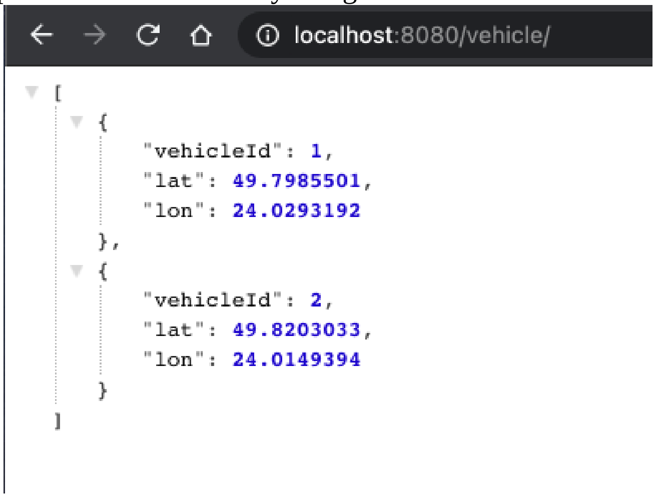
The service on the consumer side will receive up-to-date data at the time of the request, so finally, you need to configure the API-endpoint, to which the client can send requests.



```java
@RestController
@RequestMapping("/vehicle")
public class VehicleController {

    @Autowired
    private GpsService gpsService;

    @GetMapping
    public List<Position> getVehiclePositions() {
        return gpsService.getCurrentVehiclesPositions();
    }

}
```

Figure 26: Contents of the REST Controller by / vehicle

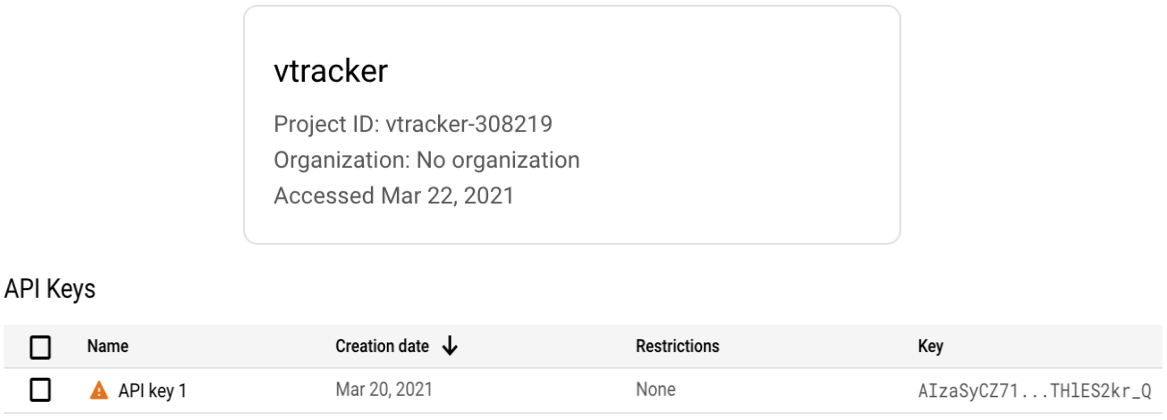
For this purpose, it is necessary to describe the REST Controller (Fig. 26) Using annotations, and in turn, Spring Boot will do all other work at the program start. Now, suppose you run the program, having previously configured everything. In that case, you can send a GET request to the link http: // localhost: 8080 / vehicle if the application was run locally and get the current data as in Fig. 27.



```
[
  {
    "vehicleId": 1,
    "lat": 49.7985501,
    "lon": 24.0293192
  },
  {
    "vehicleId": 2,
    "lat": 49.8203033,
    "lon": 24.0149394
  }
]
```

Figure 27: Response to a query by /vehicle

The next step is to configure the client part that runs on Javascript using the React.js library. Again, most of the functionality comes “out of the box”, so you only need to initialise the component that will receive data from the server and interpret it visually. The API was used to display the maps Google Maps, and the GoogleMapsAPI library for React.js has also been used to make it easier to use. To use the maps, you need to create a Google Cloud account and generate a token (Fig. 28).



vtracker

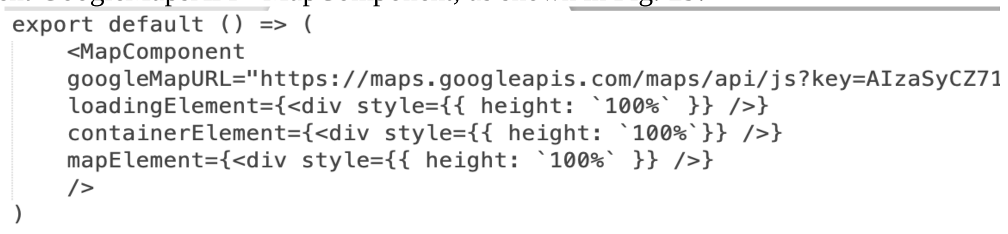
Project ID: vtracker-308219
Organization: No organization
Accessed Mar 22, 2021

API Keys

Name	Creation date ↓	Restrictions	Key
API key 1	Mar 20, 2021	None	AIzaSyCZ71...THlES2kr_Q

Figure 28: Generating an API key for GoogleMaps

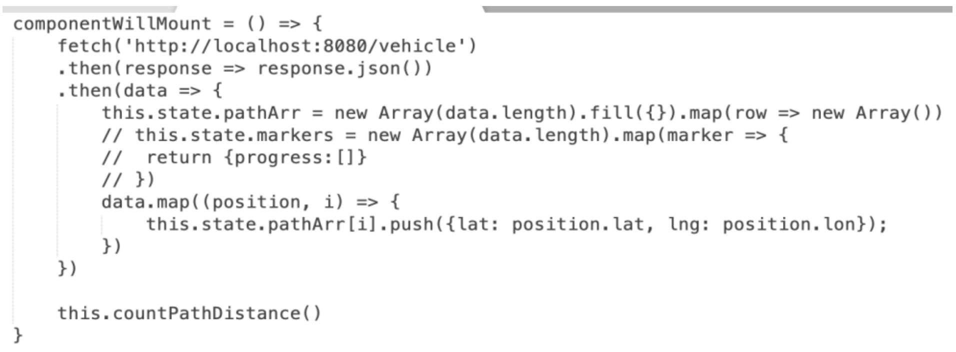
This key will be used to properly function the maps in the web application when it is launched locally. For commercial development, there are additional conditions for the operation of maps. In the created component Map.js, which will be the application’s entry point, you must initialise the component GoogleMapsAPI - MapComponent, as shown in Fig. 29.



```
export default () => (
    <MapComponent
    googleMapURL="https://maps.googleapis.com/maps/api/js?key=AIzaSyCZ71
    loadingElement={<div style={{ height: `100%` }} />}
    containerElement={<div style={{ height: `100%`}} />}
    mapElement={<div style={{ height: `100%` }} />}
    />
)
```

Figure 29: Initialise the MapComponent component

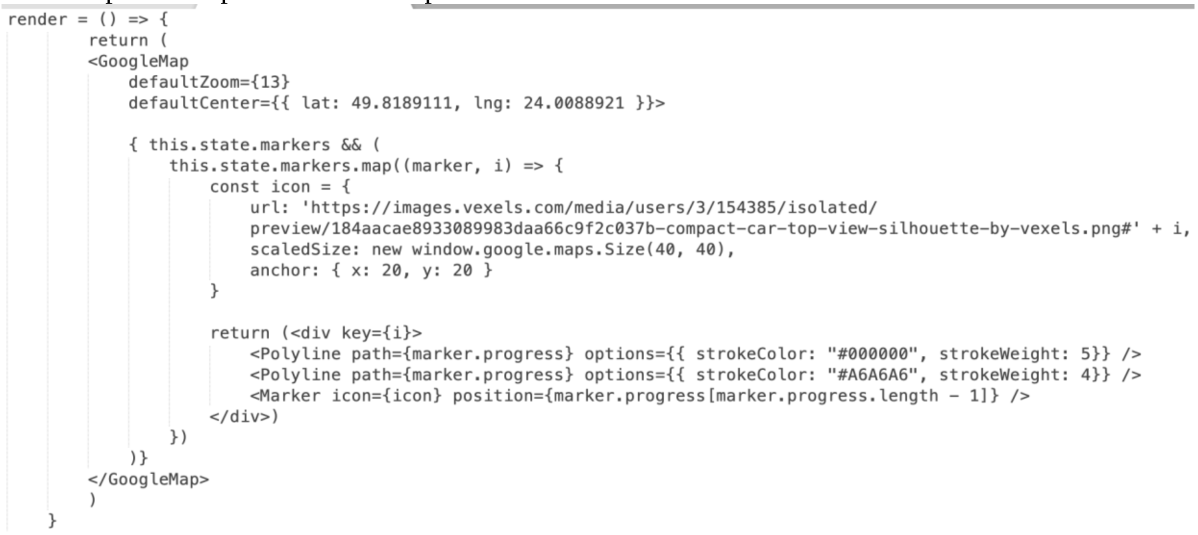
Now it is necessary to add an event to request a server to retrieve all vehicle data. Such an event will be componentWillMount, before there was a delay of 100ms for installing components - this means that the Map component will be updated ten times per second - thus updating the map’s appearance.



```
componentWillMount = () => {
    fetch('http://localhost:8080/vehicle')
    .then(response => response.json())
    .then(data => {
        this.state.pathArr = new Array(data.length).fill({}).map(row => new Array())
        // this.state.markers = new Array(data.length).map(marker => {
        //  return {progress:[]}
        // })
        data.map((position, i) => {
            this.state.pathArr[i].push({lat: position.lat, lng: position.lon});
        })
    })

    this.countPathDistance()
}
```

Figure 30: ComponentWillMount method

Omitting all the side add-ons for the correct operation of the application and the smooth movement of all components on the map, the last step is to describe the method render (Fig. 4.16.), adding all parts to the map the component status is updated.

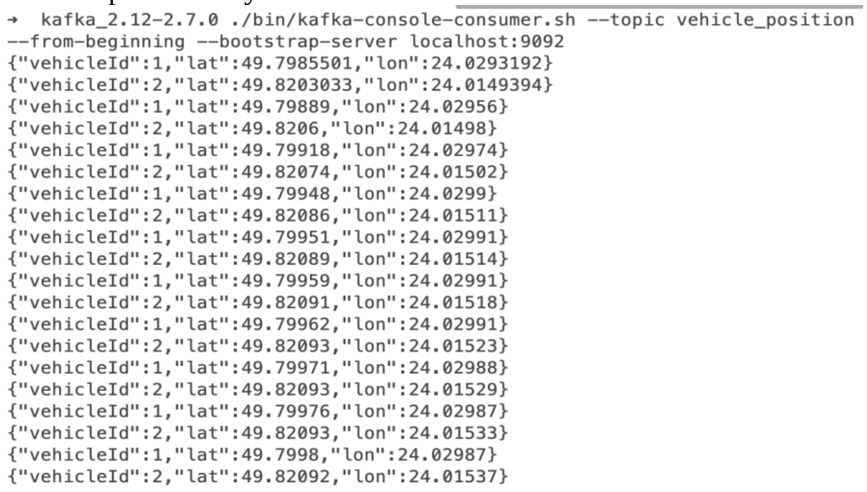


```
render = () => {
        return (
        <GoogleMap
            defaultZoom={13}
            defaultCenter={{ lat: 49.8189111, lng: 24.0088921 }}>

            { this.state.markers && (
                this.state.markers.map((marker, i) => {
                    const icon = {
                        url: 'https://images.vexels.com/media/users/3/154385/isolated/
                        preview/184aacae8933089983daa66c9f2c037b-compact-car-top-view-silhouette-by-vexels.png#' + i,
                        scaledSize: new window.google.maps.Size(40, 40),
                        anchor: { x: 20, y: 20 }
                    }

                    return (<div key={i}>
                        <Polyline path={marker.progress} options={{ strokeColor: "#000000", strokeWeight: 5}} />
                        <Polyline path={marker.progress} options={{ strokeColor: "#A6A6A6", strokeWeight: 4}} />
                        <Marker icon={icon} position={marker.progress[marker.progress.length - 1]} />
                    </div>)
                })
            )}
        </GoogleMap>
        )
    }
```

Figure 31: Initialise the render method

4.2. Analysis of the control example

First of all, you need to check whether the Apache Kafka cluster is configured and working correctly, so in the terminal window, we connect using the command shown in Figure 4.17. Now the information in the terminal will be updated every time Kafka Producer sends it.

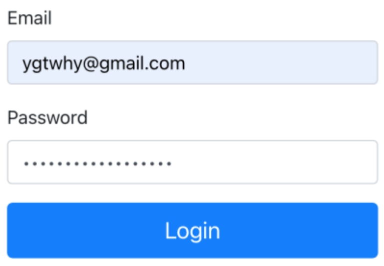


```
→  kafka_2.12-2.7.0 ./bin/kafka-console-consumer.sh --topic vehicle_position
--from-beginning --bootstrap-server localhost:9092
{"vehicleId":1,"lat":49.7985501,"lon":24.0293192}
{"vehicleId":2,"lat":49.8203033,"lon":24.0149394}
{"vehicleId":1,"lat":49.79889,"lon":24.02956}
{"vehicleId":2,"lat":49.8206,"lon":24.01498}
{"vehicleId":1,"lat":49.79918,"lon":24.02974}
{"vehicleId":2,"lat":49.82074,"lon":24.01502}
{"vehicleId":1,"lat":49.79948,"lon":24.0299}
{"vehicleId":2,"lat":49.82086,"lon":24.01511}
{"vehicleId":1,"lat":49.79951,"lon":24.02991}
{"vehicleId":2,"lat":49.82089,"lon":24.01514}
{"vehicleId":1,"lat":49.79959,"lon":24.02991}
{"vehicleId":2,"lat":49.82091,"lon":24.01518}
{"vehicleId":1,"lat":49.79962,"lon":24.02991}
{"vehicleId":2,"lat":49.82093,"lon":24.01523}
{"vehicleId":1,"lat":49.79971,"lon":24.02988}
{"vehicleId":2,"lat":49.82093,"lon":24.01529}
{"vehicleId":1,"lat":49.79976,"lon":24.02987}
{"vehicleId":2,"lat":49.82093,"lon":24.01533}
{"vehicleId":1,"lat":49.7998,"lon":24.02987}
{"vehicleId":2,"lat":49.82092,"lon":24.01537}
```

Figure 32: Consumer connection to the subject

Data comes every second, as expected. The figure shows records with vehicleId equal to 1 and 2 - this is, as mentioned above, the vehicle identifiers, so we expect the customer to receive information about the position of the two vehicles that we could see in the terminal window.

The next step is to start the REST API for the server and the npm start command to start the client part, which will be available locally by following the link http: // localhost: 3000. At this link, we get the form for authorisation, as shown in Fig. 33.


Email

ygtwhy@gmail.com

Password

••••••••••••••••••

Figure 33: Login window

After successful authorisation and authentication, we are redirected to a window with a map, which initialises the icons in cars moving according to the input data (Fig. 34 and 35).

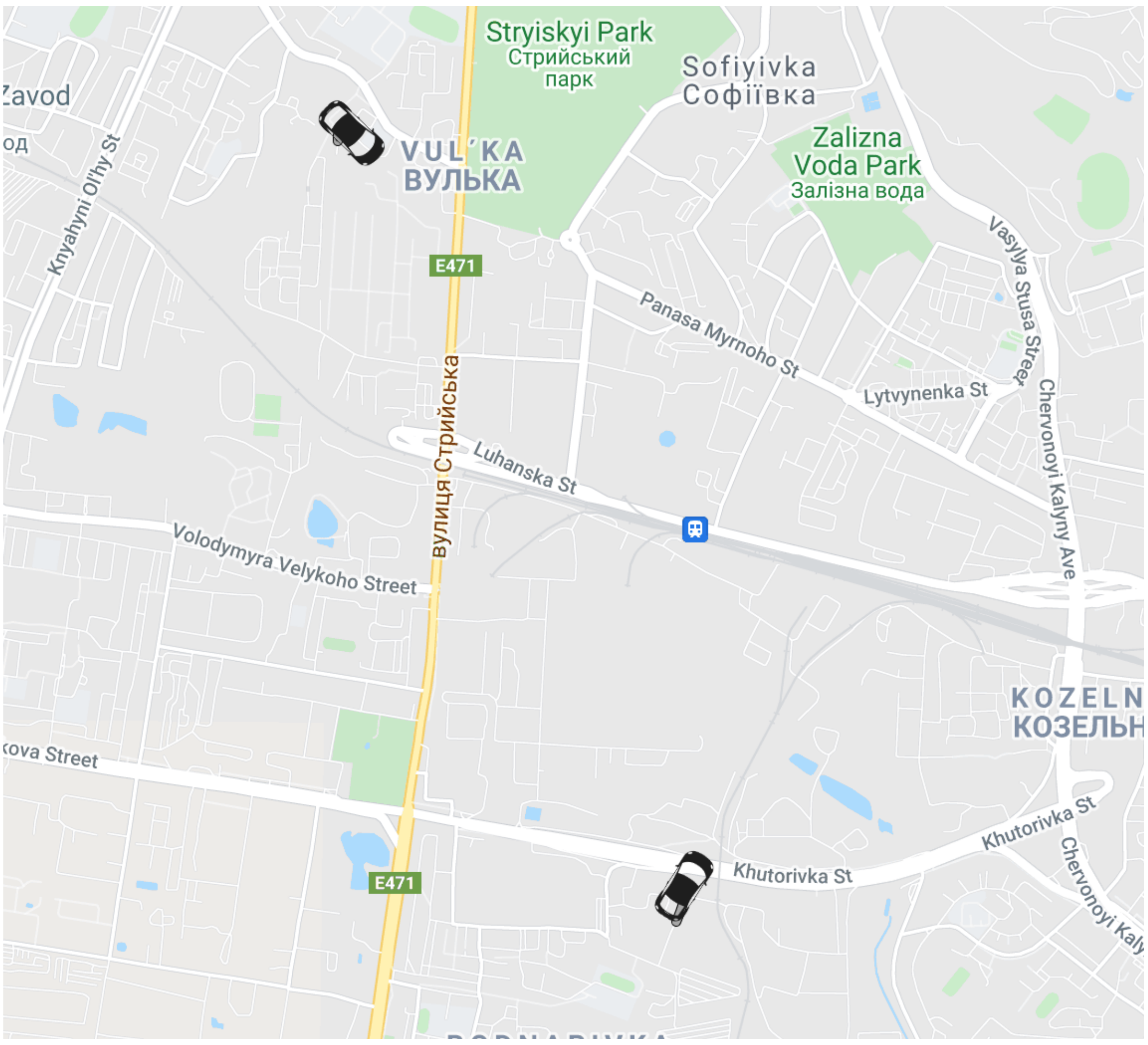
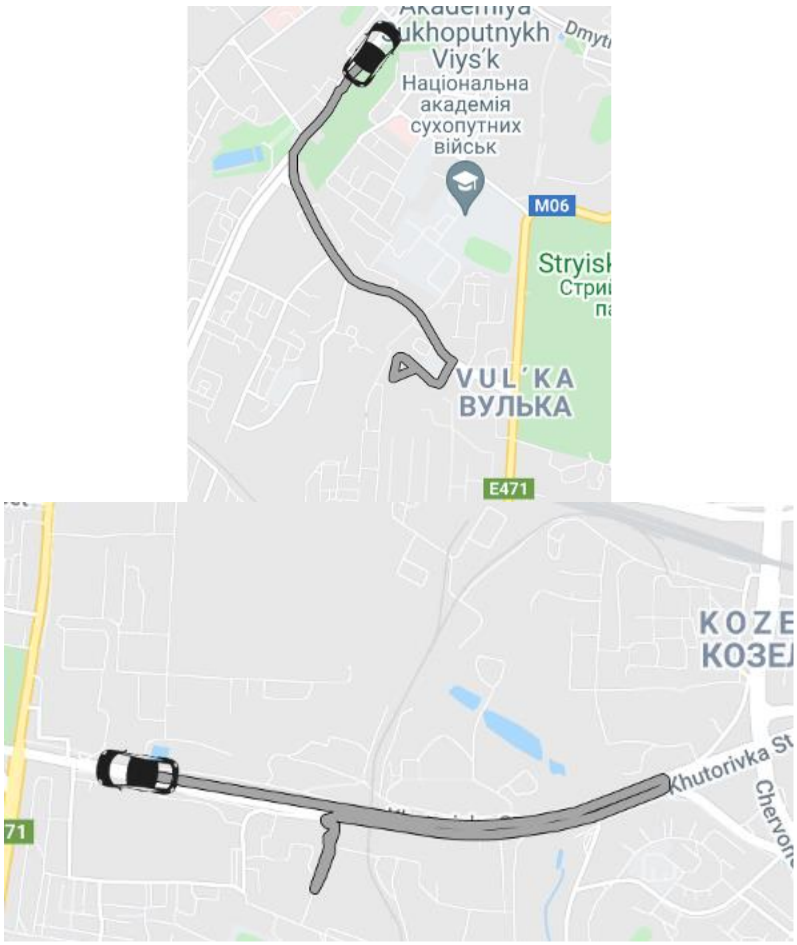


Figure 34: Initialised web application


Akademiya Sukhoputnykh Viys'k
Національна академія сухопутних військ
M06
Stryisk
VUL'KA
ВУЛЬКА
E471
KOZE
КОЗЕ
Khutorivka St
Chervon
71
Figure 35: Initialised web application

It is also possible to get additional information about a specific vehicle by clicking on it. For example, in the current version of the system, it is possible to obtain the following data: vehicle number in the design, speed in kilometres per hour (Speed), longitude and latitude at present (Lang and Lat, respectively). This information window is shown in Fig. 4.21.

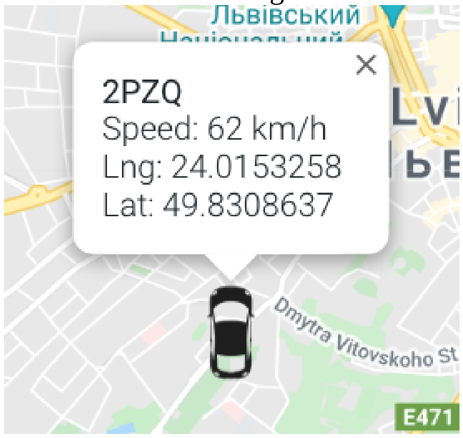

2PZQ
Speed: 62 km/h
Lng: 24.0153258
Lat: 49.8308637

Figure 36: Additional information about the condition of the vehicle

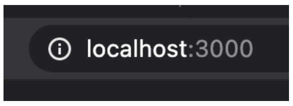
4.3. User manual

First of all, the user needs to download Apache Kafka to his personal computer to raise the cluster with the following commands: ./bin/zookeeper-server-start.sh config/zookeeper.properties./bin/Kafka-server-start.sh config / server.properties

After that, it is necessary to lift the client and the server locally. To raise the server, the main method of the VTrackerApplication class is started. The client is started with the following command:

```
npm start
```

All that remains is to follow the link shown in Fig. 37, after which the user sees all the necessary information.



localhost:3000

Figure 37: The link that the web application is running

In this section, a description of the software product was written, a database schema was created, and the client-server structure of the software was described. Also, the user manual is related to technical characteristics and step-by-step deployment of this information system analysis of the control example with graphic functional of the created system results.

5. Conclusions

The paper develops essential functions for an intelligent real-time vehicle tracking information system. The developed software product allows users to monitor the movement of their own fleet and provides additional opportunities to manage it, keep statistics, history, etc., which in some cases can help businesses of any size. At the initial stage, the basic concepts used in the creation of a real-time vehicle tracking system were identified. An analysis of the methods used by enterprises to control the fleet was conducted and identified their key features, properties of their functionalities, identified the disadvantages and advantages of such systems. After the analysis, it was determined that the topic is relevant for implementation and can be actively used in services where such performance is required.

During the development of the intelligent information system, the type of information system was also determined using the analysis of hierarchies by qualitative alternatives. A conceptual model has also been built, which consists of creating UML diagrams, such as the diagram of use cases, classes, sequences, activities, state transitions and components. Characteristics of the created system:

- Display of results in real-time;
- The application that works around the clock, if it is running on the server;
- User-friendly interface based on Google Maps;
- The ability of the system to withstand high loads;
- The ability to add new functionality and expand existing ones.

The system was created in the Java programming language. Using the platform to broadcast events has increased the speed of the application and allowed it to withstand heavy loads. The architecture of the system is built so that the developer can expand the functionality and cover the application with test cases in the future. Expansion methods include displaying more information about a particular vehicle, adding the ability to create a path for cars and track their performance, connecting managers' phones to the system to send those SMS about events, and more. It is worth noting that there are already many such solutions on the market, and the number of analogues continues to grow. Still, there is always the possibility of developing optimal solutions for specific users - the so-called customisation. Car rental companies also use it to monitor their fleets. The result of the work is the acquisition of skills in the field of logistics. In addition, improved knowledge for building systems of varying complexity, modern architectures, and the creation of high-load systems that work in real-time.

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