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METHOD FOR AUTOMATED COLLECTION, STORAGE AND PROCESSING OF INFORMATION ABOUT ARTIFICIAL SATELLITES OF THE EARTH

Abstract: The purpose of this work is to develop an information-analytical system of parameters of artificial Earth satellites, designed to accumulate, store, display and process information about artificial Earth satellites for the purpose of geolocation. To achieve this task, it is necessary to develop: special software with a graphical interface, a service for storing and providing access to information, a service for automatically collecting and updating information from open sources. It is also necessary to provide interaction with an external service for calculating trajectories.

Key words: development, information-analytical system, parameters of artificial Earth satellites.

Language: English

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Introduction

Initially, space exploration had a purely military purpose. Accordingly, some of the first artificial Earth satellites were military ones. Today, the possibilities of

satellite technology are used everywhere. Mobile communications, television, Internet access – all of this is the result of the development of the space industry.

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The first satellite "Sputnik-1" was launched into the Earth's orbit in 1957 by the USSR. Since that moment, more than 4000 satellites for various purposes have been launched into space [1].

Satellite communications have given humanity additional opportunities. The first satellite was also part of the idea of creating a global communications system. Satellite Internet is a good solution for residents of settlements located far from cellular base stations. When setting up a dish to receive a signal, one of the tasks is to obtain information about the coverage areas of the satellites of the selected provider.

On the Internet, you can find resources that provide heterogeneous information about space bodies, for example, their technical characteristics, flight path, coverage areas, etc. Due to the fact that such information is not uniform, satellite data may differ in integrity and structure. Collecting and collating information from all available sources can take a long time.

From the foregoing, it can be concluded that the aggregation, storage and presentation of such information is becoming increasingly important today.

Description of the development process

The information-analytical system of parameters of artificial Earth satellites is designed to provide a solution to the problems of heterogeneity in the presentation of information about satellites on various web resources, as well as its incompleteness.

Due to the fact that satellites can have fundamentally different sets of parameters, the properties available for use are determined by the presence of the corresponding tags for the object. The following were chosen as the main features available for tagging:

- trajectory;
- type of satellite orbit;
- type of radio broadcast: receiver, transmitter, repeater;

- belonging to the country.

The following are the main data models used in the information-analytical system.

Satellite: NORAD (North American Aerospace Defense Command) – catalog unique five-digit identification number of artificial satellites of the Earth [2]; COSPAR (Committee on Space Research) – catalog number of the flying space object in orbit and registered with COSPAR [3]; the name of the artificial satellite of the Earth; satellite model.

Transponder: transponder name; the frequency of the signal received by the satellite; the frequency of the signal sent by the satellite; signal bandwidth; beam received by the satellite; satellite beam.

Beam: beam name; polarization.

Signal: signal frequency; signal bandwidth.

Coverage Area: name of the coverage area; coverage area polygon coordinates.

Characteristics: satellite characteristics; date of entering the characteristics into the database.

Orbit: satellite inclination angle; satellite position; orbit type; date; orbit type; perigee - the point of the satellite's orbit closest to the Earth; apogee - the point of the satellite's orbit, the most distant from the center of the Earth.

Launch: satellite launch date; launch country; launch site.

Figure 1 shows the architecture of the developed system, which consists of three software modules interacting with each other:

1. Special software with a graphical user interface (hereinafter referred to as the "Browser").
2. Service for storing and providing access to information (hereinafter referred to as the "Information Access Service"). The service includes a database (DB).
3. Service for automatic collection and updating of information from open sources (hereinafter referred to as the "Information Collection Service").

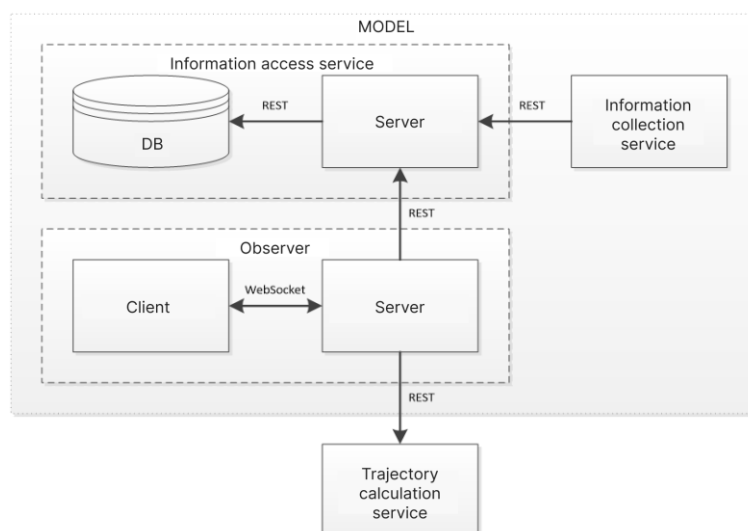


Figure 1 – Architecture of information-analytical system of parameters of artificial Earth satellites

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Information-analytical system provides:

- storage and display of technical parameters of satellites;
- classification of satellites by types, parameters, belonging to the country and additional parameters;
- display of satellite orbits;
- work with tools for working with radio receiving, radio transmitting and radio relay capabilities of satellites;
- work with the editor for working with satellite coverage areas.

For the initial filling of the storage and subsequent maintenance of it up to date, a service has been developed for collecting information from open sources on the Internet. The functions of the service include parsing and analyzing pages on portals containing information about satellites, extracting the necessary data about the general characteristics of satellites, satellite coverage areas and transferring them to the storage service using the REST interface.

In the “Information Access Service”, a database structure has been designed to store all the information necessary for the full-fledged operation of the layout. Access to the database is carried out using a service that provides a REST interface for external use. During the development of the “Information Access Service”, the following technologies were used: the C# programming language, the Entity Framework Core ORM technology, and the PostgreSQL DBMS.

After designing the infological database model, datalogical modeling of the database structure was carried out. At the datalogical level, the infological (human-oriented) model, taking into account a specific DBMS, is transformed into a computer-oriented database model.

The transformation of the infological database model into a datalogical one is carried out using the Entity Framework Core ORM technology.

A model in the Entity Framework is a collection of all entities and relationships between them that are managed by a data context. All entities that Entity Framework Core works with and that are stored in the database are defined in C# as classes. The data annotation mechanism was used as a technology for designing entity classes. Annotations represent the customization of entity classes using attributes. Most of these attributes are located in the System.ComponentModel.DataAnnotations space, which must be included before annotations can be used.

Each entity is mapped by default to a table named after the DbSet<T> property in the data context that represents that entity. If no such property is defined in the data context, then the name of the entity class is used for the table name. The Table attribute allows you to override the mapping to a table by name. By default, each property is mapped to the column of the same name. The Column attribute overrides the mapping.

Relationships between entities in Entity Framework Core use foreign keys and navigational properties. In this case, the SatelliteModel, Orbits, LaunchesSatellites, Beams, and CoverageAreasSatellites class fields are the navigation properties needed to link the Satellites table to the SatelliteModels, Orbits, LaunchesSatellites, Beams, and CoverageAreasSatellites tables, respectively.

We should also mention the element responsible for the relationship between entity classes and the database – the DbContext class. DbContext is an important class in the Entity Framework API. It is a bridge between entity classes and the database. Below is a diagram of the interaction between entity classes and the database through the context class (Figure 2).

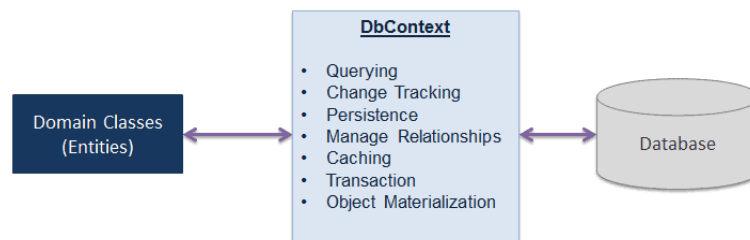


Figure 2 – Scheme of interaction between entity classes and the database through the context class

DbContext is the main class responsible for interacting with the database. He is responsible for the following activities:

- converting LINQ-to-Entities queries into SQL queries and sending them to the database;
- tracking changes that have occurred to entities after a query from the database;
- performing insert, update, and delete operations on the database based on object states;

- providing first-level caching by default. This level stores entities that have been retrieved during the lifetime of the context class;
- relationship management with CSDL, MSL, and SSDL in a Db-First or Model-First approach, and using flexible API configurations in a Code-First approach;

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- converting raw data from the database into entity objects.

Database initialization is carried out using the first data migration. Using migrations is the standard way to create and update a database with Entity Framework Core. The migration process consists of two steps: creating a migration and applying the migration.

To create a migration in the Package Manager Console window, enter the following command:

```
Add-Migration migration_name
```

The name of the migration is an arbitrary name, the main thing is that all migrations in the project have different names.

After creating the migration, you need to apply it using the command:

```
Update-Database
```

After the completion of the operation, the database will be initiated, in accordance with the structure described by the entity classes in the context class.

Most data operations are somehow CRUD operations (Create, Read, Update, Delete), that is, create, get, update, and delete. Entity Framework Core makes it easy to do all of these things. Next, the algorithms of the main operations will be considered.

Adding. To add an object, use the Add method defined in the DbSet class, to which the added object is passed. This method sets the value Added as the state of the new object. Therefore, the db.SaveChanges() method will generate an INSERT statement to insert the model into the table.

Removal. Removal is done using the Remove method. This method will set the status of the object to Deleted, which will cause the Entity Framework to generate a DELETE SQL statement when executing the db.SaveChanges() method.

Editing. When an object changes, the Entity Framework itself tracks all changes, and when the SaveChanges() method is called, an UPDATE SQL statement will be generated for this object, which will update the object in the database.

Search for a record by ID. When passing a satellite identifier to the input parameter of the method, a search is made for the corresponding entity class

identifier in the context class using the Find method. The return type is the model class converted from the found entity class.

Reading all records in a table. The Select extension method is used to get objects. This method accepts a transform function as a Func<TSource,TResult> delegate. The transform function takes each sample object of type TSource and uses it to create a TResult object. The Select method returns a collection of converted objects.

Similarly, CRUD operations were developed for the following models: SatelliteModel, Launch, LaunchSatellite, Orbits, Transponders, Characteristics, BaseObjects, Beams, Signals, Polarizations and CoverageAreas.

The “Browser” is implemented as two software modules that must run on a desktop PC or mobile device. The “Browser” provides the user with the ability to search and group satellites according to various sets of filters; viewing information on satellites of interest, its editing; viewing positions, trajectories and coverage areas on a three-dimensional map.

The server part of the “Browser” is responsible for the functioning of the information-analytical system and provides links between the modules that make up it. The server functions as a service on a separate PC and interacts with the rest of the layout through the local area network TCP/IP.

The interaction of the server side of the “Browser” with the storage service is carried out using REST. Interaction with the service for obtaining coordinates is carried out using REST. Interaction with the user interface is carried out using the WebSocket protocol.

The service for calculating the trajectory of relay satellites calculates and provides the layout with data on their trajectories for specified time ranges. The interaction is carried out using the REST architecture.

The external interaction module provides access to the database. The interaction of the server part of the information access service with the storage service is carried out using the REST architecture. Interaction with the “Information Collection Service” is also carried out using the REST architecture.

Figure 3 is a flow diagram describing the general capabilities of working with satellite information.

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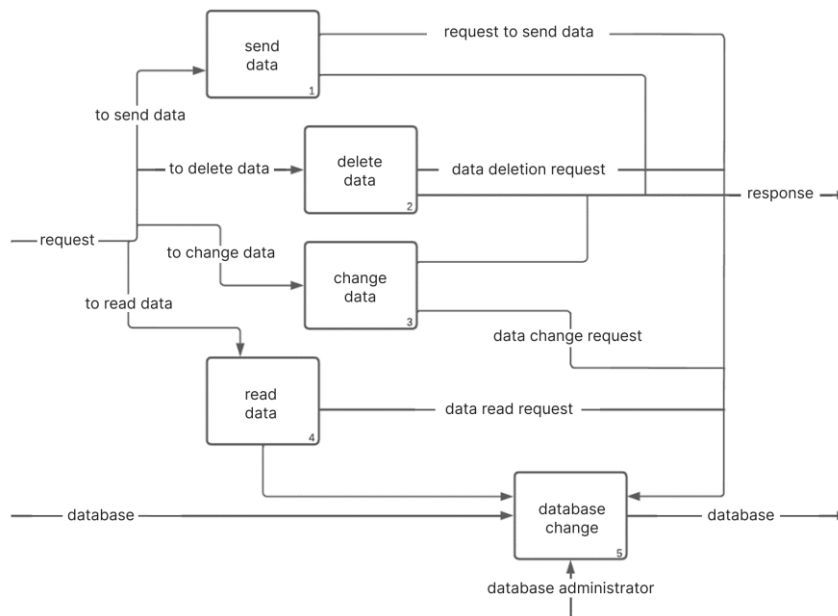


Figure 3 – Flow diagram "Processing service client requests"

The interaction between the components occurs through requests-responses, which are sent via the HTTP protocol. In addition to HTTP status codes, a proprietary format for status messaging was developed: status as a numeric value (1 - success, 2 -

error) and a text message about the result of receiving and processing the request. Figures 4 - 5 show the process of communication between the Server part of the "Browser" or the "Information Collection Service" and the Database Server with the Database.

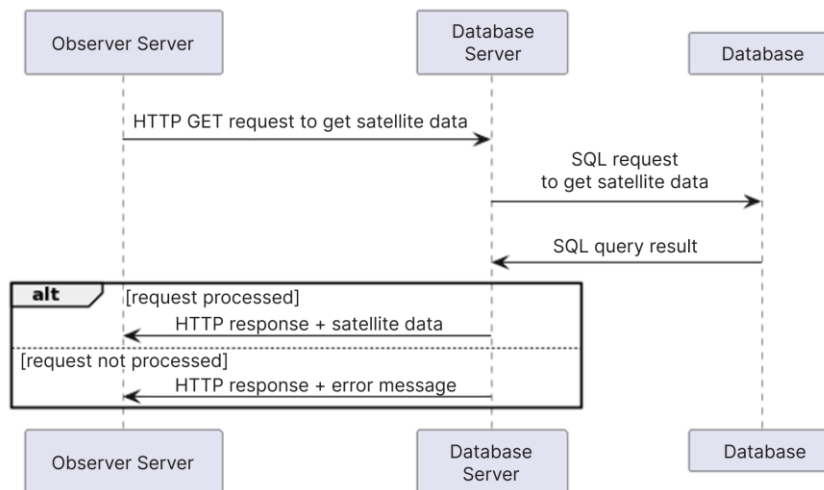


Figure 4 – Sequence diagram "Data exchange between "Browser" server and database server"

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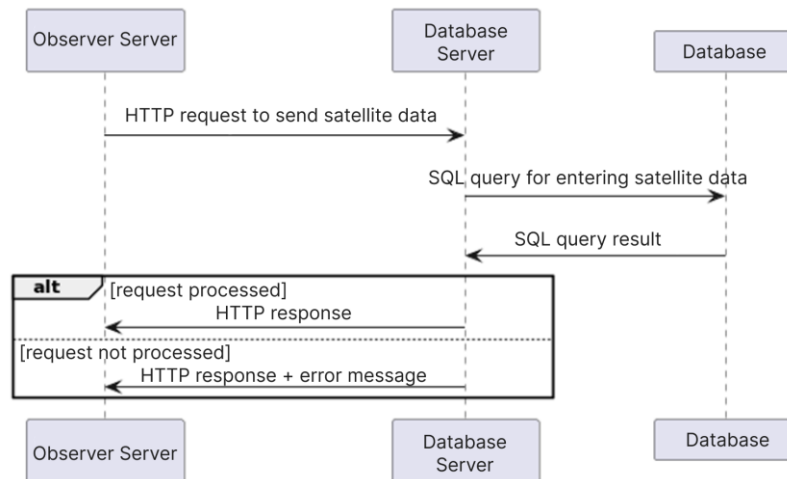


Figure 5 – sequence diagram "Data exchange between the "Information Collection Service" and the Database Server"

Data exchange takes place in JSON format. In this paper, the JSON structure is in the format of a collection of name-value pairs.

The following is the structure for getting data in JSON format.

```

{
  "Payload": [ {
    "IdBeam": "...",
    "PolarizationId": "...",
    "Name": "...",
    "SatelliteId": "..."
  }
],
  "Status": [...],
  "ErrorMessage": "..."
}
  
```

The above is an example of the structure of a JSON response to a GET request for the data of the "Beam" table record. The response body is wrapped in the "Payload" structure, the status of the request processing "Status" and the message "ErrorMessage" with a description of the result are additionally indicated. In this case, as you can see, the processing of the request was successful.

Information about the beam is presented in the form of the following fields:

- "IdBeam" - identification number (ID) of the beam record;
- "Polarization" - information about the polarization of the beam;
- "Name" - the name of the beam;
- "SatelliteId" - ID of the satellite that this beam belongs to.

The following is the structure for sending a response in JSON format.

```

{
  "Status": [...],
  "ErrorMessage": "..."
}
  
```

This example shows the structure of the response as a result of unsuccessful request processing. The "ErrorMessage" contains a message about the exception that occurred during the execution of the request on the server.

The external interaction module implements the following groups of functions:

1. Obtaining, saving, editing and deleting general information about the satellite, including its tags.
2. Obtaining, saving, editing and deleting the list of antennas (beams) operating on satellites with additional information about them.
3. Obtaining, saving, editing and deleting a list of satellite radio frequency parameters.

The general information about the satellite that will be obtained in the first group of functions includes the technical characteristics and description of the satellite.

The second group of functions extracts information about the receiving and transmitting antennas. In addition, information will be provided on the polarization of the rays and the geographical regions of coverage.

The radio frequency parameters of the satellite, which will be obtained using the third group of functions, include:

- transponders (transceivers) – frequency plans containing ascending and descending frequency ranges with reference to beams;
- receivers – uplink with beam lock;
- transmitters – downlink with beam lock.

The functionality of the external interaction module was implemented using the REST architecture.

At the moment, the external interaction module is able to asynchronously process the following requests:

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• GET – getting all the data of the database table;

- GET – getting table field data by ID;
- POST – sending data;
- PUT – record editing by ID;
- DELETE – delete record by ID.

As part of the implementation of the client part of the open source software, the following tasks were set: to provide a convenient interface for viewing information, satellite characteristics, which allows displaying the position of satellites, their trajectories in a given time interval and coverage areas on a 2d and 3d map, as well as facilitating the process of complex analysis of information about satellites, aimed at obtaining more accurate predictions and solutions in the field of geolocation and other related areas.

As part of the development of the client part of open source software, the following technologies were used:

- TypeScript programming language;
- React JS library;
- React Router Library;
- Redux Library;
- Material UI Component Library;
- CesiumJS Library;
- Jest testing library.

TypeScript programming language. TypeScript is a programming language based on JavaScript.

Main advantages of TypeScript:

- TypeScript is a strongly typed and compiled language. Strong typing reduces the number of potential errors.
- TypeScript implements many of the concepts that are native to object-oriented languages, such as inheritance, polymorphism, encapsulation and access modifiers, and so on.
- The potential of TypeScript makes it faster and easier to write large, complex programs, and therefore easier to maintain, develop, scale, and test than with standard JavaScript.
- TypeScript is developed as an open source project.
- Is cross-platform.

React library. React is an open source JavaScript library for developing user interfaces. This library is based on the idea of declarative programming. [9]

The key feature of this library is that React is based on components. Each component returns a part of the user interface with its own state. Combining components, we get a complete web application interface.

An important feature of React is the use of JSX. This is a JavaScript syntax extension that is useful for describing an interface. JSX allows you to write

JavaScript code using ready-made components that almost completely repeat HTML. This simplifies development.

Important features of React include the use of the virtual DOM (Virtual DOM). Virtual DOM is an object that stores information about the state of the interface. When the state changes, React calculates the difference between the old and new state. The library then renders the new state. Using the virtual DOM allows the library to update the real DOM efficiently.

React Router. React is a library for building Single Page Applications (SPA).

React Router is the default routing library for React. [8] Routing is the process of synchronizing the “Browser” URL with what is displayed on the page. The library allows you to set up URL routes for certain React components that need to be rendered as separate pages.

Redux. The Redux library is a way to manage application state.

In Redux, the overall state of the application is represented by a single JavaScript object - state (state) or state tree (state tree). The immutable state tree is read-only, nothing can be changed directly. Changes are possible only when sending action (action).

The Store contains the state. A store is an object that:

- contains the state of the application;
- displays the state via getState();
- can update the state via dispatch();
- allows you to register (or remove) as a state change listener via subscribe().

An action is a JavaScript object that concisely describes the nature of the change. The only requirement for an action object is a type property, which is usually a string.

When an action starts, the state of the application changes. This is the job of gearboxes. A reducer is a pure function that calculates the next state of a tree based on its previous state and the action to take. The reducer returns a brand new state tree object that replaces the previous one.

Material UI. Material UI is a library that is a collection of React components. It has components for layouts, forms, navigation, data display, and many other widgets. This library simplifies development due to a large set of ready-made components with a custom design.

CesiumJS Library. Cesium is an open source JavaScript library for creating virtual globes and maps in a web “Browser” without the use of plug-ins, using WebGL technology for hardware accelerated graphics and dynamic data visualization capabilities.

Main features [7]:

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- 2D and 3D viewing modes;
- visualization of the Earth's relief with high resolution;
- visualization of these files in GeoJSON and TopoJSON formats, textured and animated three-dimensional models in COLLADA and glTF formats, drawing and setting display styles for a wide range of geometric shapes: polylines, posters, labels;
- drawing and adding objects to the relief, working with the following graphic primitives (including the extrusion operation): polygons, polygons with holes, rectangles, circles and ellipses, boxes, spheres, ellipsoids and cylinders, corridors and walls.

Next, the principle of storing, displaying and processing data will be considered.

Redux store is used as a data store. Redux implements the idea of the Flux architecture. This is the architecture responsible for creating the data layer in JavaScript.

Flux architecture is an architectural approach for building the user interface of web applications, combined with reactive programming and built on unidirectional data flows. In the Flux architecture, the global state of the application is stored in storage and separated from the components. And changing the state is done through reducers. The general principle of operation is shown in Figure 6.

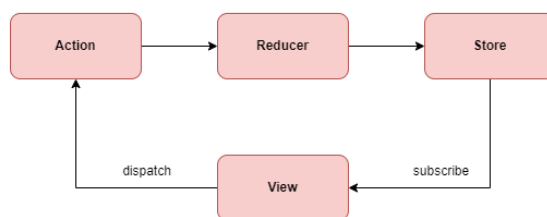


Figure 6 – Flux architecture - principle of operation

The principle of operation and the role of the components of the flux-architecture [5]:

- In the "action" field, there is some kind of interaction with the application.
- Action calls special methods that set constants to these interactions and send them to the reducer.
- The reducer handles the received event. It distinguishes the received event by its sources. After processing the event, it sends it to all registered event handlers, that is, to the store.
- The Store receives this event and defines a handler for it. The store then responds to the received event and fires another "changed" event that defines the state of the application as a response to interacting with it.
- "View" (View) "listens" to the store and, as soon as it detects the "changed" event, it immediately reacts to it, updating itself and its own React components.

Next, the organization of interaction with the server part of the open source software will be considered.

Data exchange between the client and server parts is performed using the WebSocket protocol by means of data exchange in JSON format.

To integrate WebSocket into the React / Redux architecture, the so-called middleware was used - middleware.

General principle of middleware operation:

1. Middleware are built into the repository when it is created.
2. During dispatch (sending actions), the data passes through them and only then gets into the reducer.

Middlewares provide a third-party extension point between the dispatch of an action and the moment that action reaches the reducer.

The way the middleware was built in to organize interaction with the server via the Websocket protocol is clearly shown in Figure 7. The process of connecting to the server is presented in the form of a flowchart (Fig. 8).

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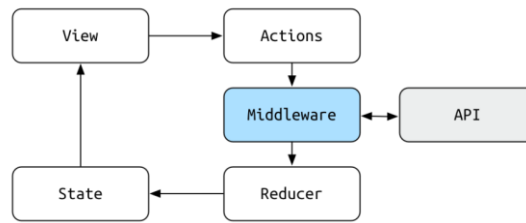


Figure 7 – Embedding middleware in the application architecture

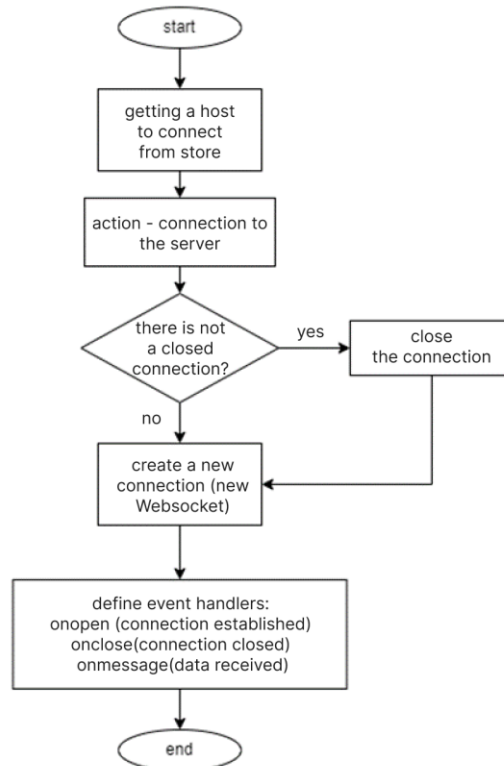


Figure 8 – The process of connecting to the server

Next, consider the interface and nesting of components depending on the url.

When satellites are selected, the SatelliteItem component appears. In which routing is also configured. When url = "/", "/info", or "/satellite" the SatelliteCards component is displayed with cards (SatelliteCardItem components) with brief information about satellites – names and identifiers.

When url = "satellite/:id" (where ID is a specific satellite identifier), which can be accessed by clicking on the "detailed information" button on the satellite card, the SatelliteAllInfoLayout component is displayed.

The SatelliteInfo component contains drop-down blocks with information about the satellite. The SatelliteNavigation component has functionality for quickly switching between pages with information of selected satellites.

When creating a map, all the necessary parameters and settings are set. After the map is created, it is drawn.

Further, for all selected satellites, a request is sent to receive their coordinates, and according to the received data, the satellites are plotted on the map.

The coverage areas of satellites in terms of representing them in a graphical form can consist of several figures. Currently rendering is based on the following elements:

- polygon (constructed according to a given set of points - geographical coordinates);
- circle (constructed according to the given radius and coordinates of the center);
- sector (constructed according to the given inner and outer radius, initial and final angle of rotation and coordinates of the center).

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JIF	= 1.500	SJIF (Morocco)	= 7.184	OAJI (USA)	= 0.350

The satellite's flight trajectory is displayed by drawing a broken line on the map by points - the geographical coordinates of the satellite's location at a point in time. To draw the trajectory, you must set the time interval – the start and end date and time.

Satellite coordinates in text view can be obtained from the context menu in the list of satellites. You can also center the map on a specific satellite by clicking the corresponding context menu button in the list. The color of the trajectories can also be changed for each satellite separately - this is convenient when overlaying trajectories when viewing information on several satellites at once. When choosing a start and end time for building a trajectory, there are the following intervals in quick access – for the last day and for the last week, you can also set these parameters manually.

Thus, the application interface was divided into several pages. The main ones are pages containing structured and grouped information about satellites and a page with a map, which graphically presents information about satellite locations and their coverage areas. Using the map tools of the CesiumJS library, information about the locations of satellites and their coverage areas was visualized, which increases the convenience of human perception of this information, and also allows for primary data analysis.

Conclusions

In this work, an information-analytical system of parameters of artificial Earth satellites was developed, designed to accumulate, store, display and process information about artificial Earth satellites for the purpose of geolocation.

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