MEASUREMENT OF NON-ELECTRIC QUANTITIES

MAP OF STATE OR CURRENT SITUATION DISPLAY FOR THE DISTRIBUTED ACOUSTIC SENSOR SYSTEM

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Abstract. The research focuses on creating software for an interactive map that displays the air environment based on data collected from a distributed system of acoustic sensors. This development aims to enhance Ukraine's defense capabilities in wartime and opens prospects for further research in this field. The map allows operators to analyze information about the movement of air targets in real time, which is important for making quick and informed decisions in the field of defense and security. The development of this system also opens prospects for future research, such as expanding the map's functionality, integrating it with other systems, and further optimizing the operation of acoustic sensors. Our work is aimed at ensuring Ukraine's national security and defense capabilities.

Keywords: Acoustic sensors, sensor system, software, data processing, information system, acoustic monitoringte.

1. Introduction

Ukraine, which has been in a state of full-scale war with the rf since February 24, 2022, faces complex and extremely important tasks in ensuring national security and protecting its population. The situation, in which the enemy uses cruise missiles, ballistic missiles, and kamikaze drones [1], poses a serious threat that requires us to develop and implement the most advanced methods of monitoring and forecasting the air situation.

In an interview with The Economist, Commander-in-Chief of the Armed Forces of Ukraine Valerii Zaluzhnyi pointed out the systemic risk associated with drones: “Russian drones have taken over a significant part of the functions of manned aviation in terms of reconnaissance and air strikes” [2].

One of the most pressing tasks is to ensure reliable and rapid control of airspace, as well as to identify and track potential threats and dangers in this area. It is in this complex context that there is a need to develop and implement innovative systems capable of providing real-time information about the air situation.

Providing timely and accurate information about the current situation and the movement of airborne objects is becoming a critically important task. Traditional methods of observation and reconnaissance have their limitations, especially when the enemy uses tactics to minimize radar and visual visibility.

In this context, acoustic sensors are becoming increasingly important, as sound is one of the key informative characteristics that can be used to detect and classify objects in the air. Acoustic sensors can be a reliable source of information in conditions where other means of observation are less effective.

2. Drawbacks

Currently, there are several different approaches to detecting airborne targets in wartime conditions. Radar systems [3] use electromagnetic waves to search for and determine the coordinates of targets. The principle of operation of such systems is to send radio signals and receive their reflections from objects in the air. Optical systems [4], on the other hand, rely on the use of visible and infrared radiation emitted by airborne targets. These systems can provide more detailed images but are limited by weather conditions and optical distortion by the enemy.

Among other approaches, video surveillance systems [5] are worth mentioning. They are based on the use of video cameras and specialized image processing algorithms. Such systems can detect the movement of objects, including airborne targets, and display them on a monitor in real time.

Acoustic systems are also used, which can operate in conditions of limited visibility and radio silence. Research [6] has shown that acoustic sensors can detect kamikaze drones at about 2.6 km and cruise missiles at a distance of up to 8.2 km, confirming the reliability and practicality of such systems.

One of the initiatives is a system known as “Sound” [7], which was developed by servicemen of the 125th separate brigade of the Territorial Defense Forces of the Armed Forces of Ukraine. It is designed to detect acoustic signals caused by the movement of airborne objects such as aircraft and drones.

It is important to note that information about some modern systems may be limited or classified, but it is known that there are certain acoustic detection systems [8] created for civilian and military purposes.

Despite existing solutions, the development of software with an interactive map is an innovative direction. It allows data from acoustic sensors to be collected and displayed on a geographic map, providing a convenient way to analyze the situation. This interactive approach allows for quick response to new information and identified targets, enabling faster and more effective decision-making.

3. Goal

This research aims to address the urgent and complex challenge of ensuring security and defense capabilities in the context of the full-scale war currently being waged in Ukraine. The growing threat from various aerial objects, such as drones, missiles, and aircraft, requires the development of innovative systems and technologies for detecting, tracking, and analyzing events in airspace.

The main objective of this research is to create software that can collect and analyze data from acoustic sensors designed to detect airborne targets. Such software must be reliable, efficient, and capable of operating in real time. This is important for responding quickly to potential threats and making timely decisions.

The overall goal of this research is to improve monitoring and security systems, especially in conditions of active military conflicts and threats from airborne objects. Our work is aimed at ensuring Ukraine's national security and defense capabilities in emergency conditions.

4. System Architecture

At the beginning of the system architecture development process, our team faced an important task — to develop an overall concept that would meet the needs and requirements of the project. This initial phase is critical because it determines the further deployment of the project and the success of its implementation. Choosing the right architectural approach was critical to ensuring the reliability, performance, and scalability of the system.

During the discussion and analysis, several key requirements were identified:

• Real time: The system must provide data in real time, as this is necessary for the timely detection and response to airborne threats.

• Reliability: Data collection and processing must be reliable, as the effectiveness and accuracy of the system depend on it.

• Scalability: The system must be able to scale to handle large amounts of data and support the addition of new sensors and resources.

• Security: Ensuring the protection of data and the system from unauthorized access was a priority.

• Ease of use and integration: the developed system must be easy to use and integrate with other systems.

The system's operating principle is based on a client-server architecture, where the clients are acoustic sensors and the server is a web server [9]. During operation, the sensors send requests containing their own geographic coordinates, the identifier of the detected target, its azimuth, location angle, and time of detection. The server's algorithm is similar to that of a distributed sound artillery reconnaissance system [10]. It ensures the formation and maintenance of a queue of requests, their aggregation, calculation of geographic coordinates, and plotting of targets on a map.

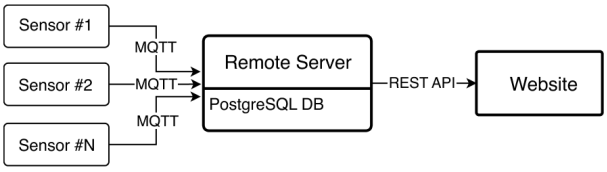

Fig.1. Schematic representation of the system's operational flow

Fig. 1 shows a diagram depicting the architecture of the remote monitoring system, which includes a set of sensors and server support. Each sensor (labeled “Sensor No. 1,” “Sensor No. 2,” up to “Sensor No. N,” where N is the number of sensors) transmits data via a 2G network using the MQTT protocol [11] to a remote server. MQTT ensures reliable message delivery even in unstable connection conditions. It is based on a “publish-subscribe” model, which allows sensors to publish data and the server to subscribe to “topics.” This allows for the efficient organization of data exchange between multiple sensors and the server. This is important for a system that receives data from sensors in real time. On the server, the data is written to a PostgreSQL database. The remote server, in turn, interacts with the website via REST API [12], allowing users to view data through the website interface.

5. Client-side development

When developing the client-side of the system to display the air situation and interaction with acoustic sensors on the map, the choice of technologies for creating the client-side was an important step that determined the quality and performance of our web application. The main factors were the speed of information display and the loading speed of the web page.

The use of TypeScript [13] was a key factor in ensuring code stability and reliability. Static typing helped to identify and avoid errors in the early stages of development, which reduced the risk of misunderstandings and increased developer productivity.

The decision to use the React library [14] together with React DOM was influenced by many factors that had a decisive impact on the success of our project development. React is known for its high performance, which allows to create interactive interfaces and respond quickly and efficiently to changes. One of the key advantages of React is its virtual DOM. It minimizes manipulation of the real DOM, as React performs internal optimizations and efficiently updates only those parts of the page that have changed. This leads to a significant increase in the speed of information display and an improved user experience. React has many third-party libraries and components that allow developers to quickly

create complex interface functions without having to write code from scratch. This saves time and effort in development and helps keep the code more structured and readable.

The Axios library [15] for making HTTP requests to the server. This library provides a convenient interface for making requests and processing responses from the server. It was important to develop optimal logic for processing requests and responses to reduce the number of requests and the amount of data transfer, which affects the page loading speed.

We chose the Mapbox GL library [16] to display geographic data on a map for several reasons, one of which was its ability to work with vector maps rather than raster maps. This choice was justified by the following factors:

• Vector maps typically have much less data than raster maps, which improves performance and page loading speed. This is especially important when dealing with large amounts of geographic data that need to be displayed in real time.

• Using vector maps allows us to create interactive applications that can be less burdensome when working with many objects on the map. This is because vector data is smaller in size and allows us to efficiently manage the display and interaction with objects on the map. This approach helps improve the user experience, especially when working with large amounts of data.

• Vector maps allow to precisely customize the style and appearance of the map, including colors, objects, text, and other attributes. This makes it possible to create beautiful and informative maps that meet the needs of the project.

When creating an interactive map, we implemented testing for displaying many objects. One of the solutions for optimizing map display was the use of clustering. Clustering allows to group geographically close objects at a single point on the map, which greatly simplifies visual perception and improves performance when there are many objects on the map. This approach allows users to easily analyze and interact with many objects on the map, providing convenient and quick access to information.

It is important to note that the choice of technologies required careful analysis and a sensible approach, as the performance and efficiency of the system depended on them. Properly selected technologies contributed to the fast and reliable display of information and optimization of web page loading, making our system an excellent tool for monitoring air conditions and acoustic sensors.

6. Server-side development

When developing the server-side of our system, we paid special attention to choosing technologies and tools that would help ensure the reliability, performance, and scalability of the application.

The Go (or Golang [17]) programming language became the main tool for developing our server-side for several important reasons. First, it is known for its high performance and code execution speed. This was critical for a real-time system where data processing speed is key.

To ensure the reliability and scalability of our system, we used Docker [18]. This tool allowed us to package the application and all its dependencies into containers, which simplified the deployment and scaling of our system. Docker made it easy to move and run the application in different environments.

PostgreSQL database [19]. This relational database is known for its reliability, scalability, and ability to handle complex queries. It allowed us to efficiently store sensor data, weather information, and provide security and user authorization. Advantages of using it:

• Reliability: PostgreSQL is known for its reliability and stability. It has data recovery mechanisms that prevent information loss in the event of accidents or failures.

• Extensibility: PostgreSQL is easily extensible and scalable. This allows to add new tables, indexes, and other objects to accommodate growth in data volume and database load.

• Support for complex queries: PostgreSQL has powerful capabilities for executing complex SQL queries. This allows to efficiently select, filter, and aggregate data to obtain the information need.

• Flexibility: PostgreSQL supports a variety of data types, including geographic and text data. This makes it an ideal choice for projects that require the storage and processing of different types of information.

• Security and authorization: PostgreSQL has powerful tools for ensuring data security and user authorization. You can easily configure data access rights and ensure data confidentiality and integrity.

The server part of our application includes a variety of functionality that has been implemented with performance and reliability requirements in mind. We have implemented an authorization system with different types of roles for users to ensure security and access control. Logging into the system helps track events and test the application. Interaction with acoustic sensors and real-time processing of their data has been implemented to accurately reflect the air situation. The integration of weather information and the ability to collect statistics and perform analytics have increased the usefulness of the application.

All these solutions were chosen with performance, reliability, and usability in mind, and they allowed us to create a reliable and efficient server for our system.

7. Software testing

During the development and improvement of our system, we paid great attention to software testing. The purpose of testing was to ensure the reliability and efficiency of the system before its commissioning.

First, we conducted functionality testing to verify that all basic system operations were performed correctly. This included verifying the correctness of data collection from sensors, processing this data, and displaying it on the map. We also tested the authorization and user role capabilities.

The system was subjected to load testing to ensure that it could operate stably and efficiently with large amounts of data and users. We created scenarios with many requests and simultaneous connections to evaluate the system's performance.

Security was one of the most important aspects of testing. We conducted penetration testing to identify potential vulnerabilities and security risks. We also tested the system for compliance with security standards and implemented data protection mechanisms.

8. Research results

To ensure convenience and intuitiveness of use, we have carefully designed the user interface of our system. Let's look at some key aspects of the interface and its capabilities.

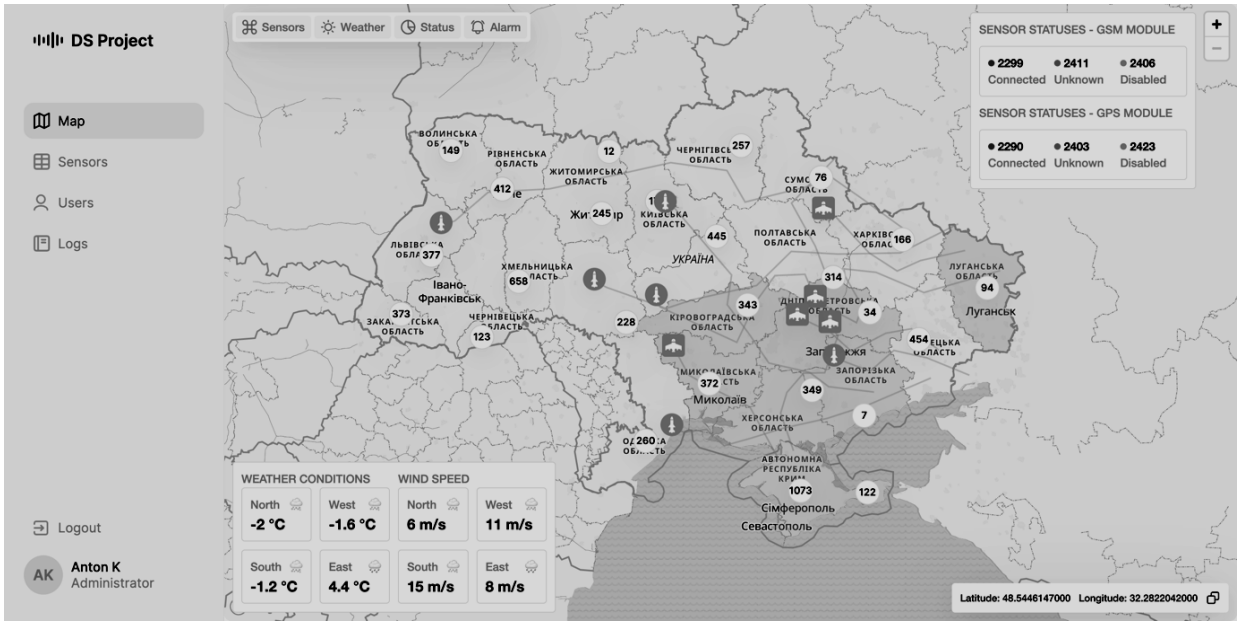

Fig.2. Interactive map interface

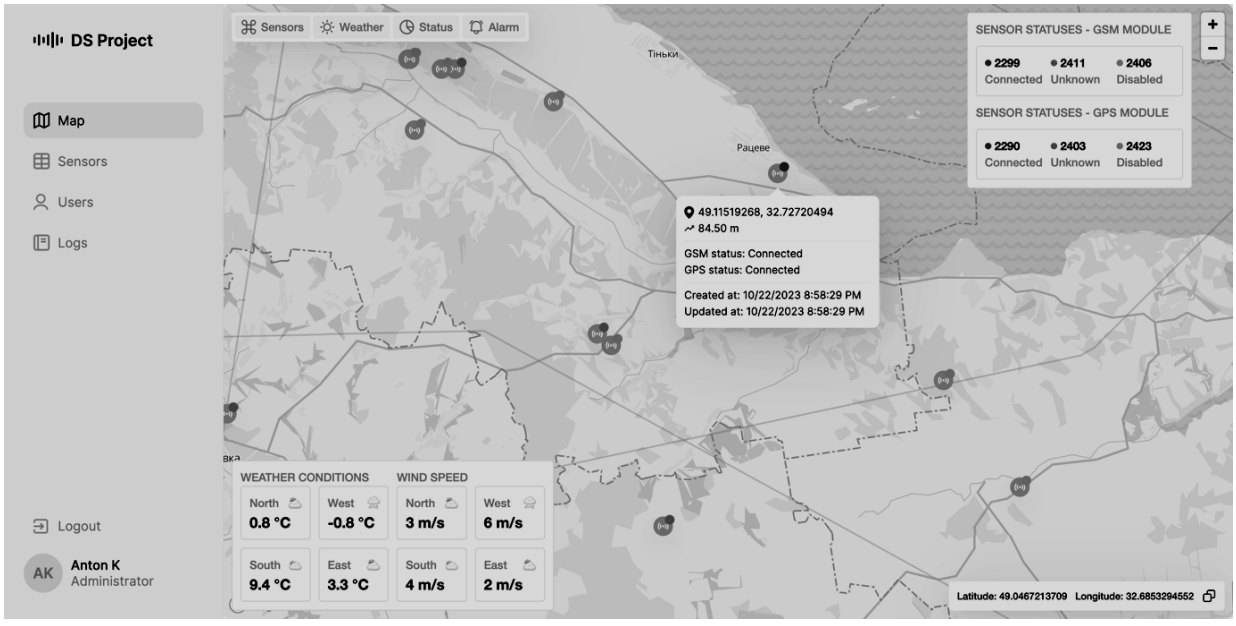

Fig. 3. Interactive map interface with enlarged scale

Fig. 2 shows the main page with navigation on the left and an interactive map on the right, which displays data on the air situation. There are also various information panels and control panels. On the map we see an example of the movement of air targets, the current threat status by region, and sensor groups in clusters are marked with a number — the number of sensors in each cluster. The system allows users to track the movement of drones, missiles, and other objects in the air. The large scale of the image allows to quickly respond to any events.

Fig. 3 shows an interactive map with an enlarged scale, which shows that at this stage there are no clusters, and the sensors are located separately. This allows users to view and obtain information about each of them separately, providing a more detailed overview of objects and their characteristics. This display mode allows users to obtain accurate and specific information about each sensor, which can be useful for analysis and decision-making.

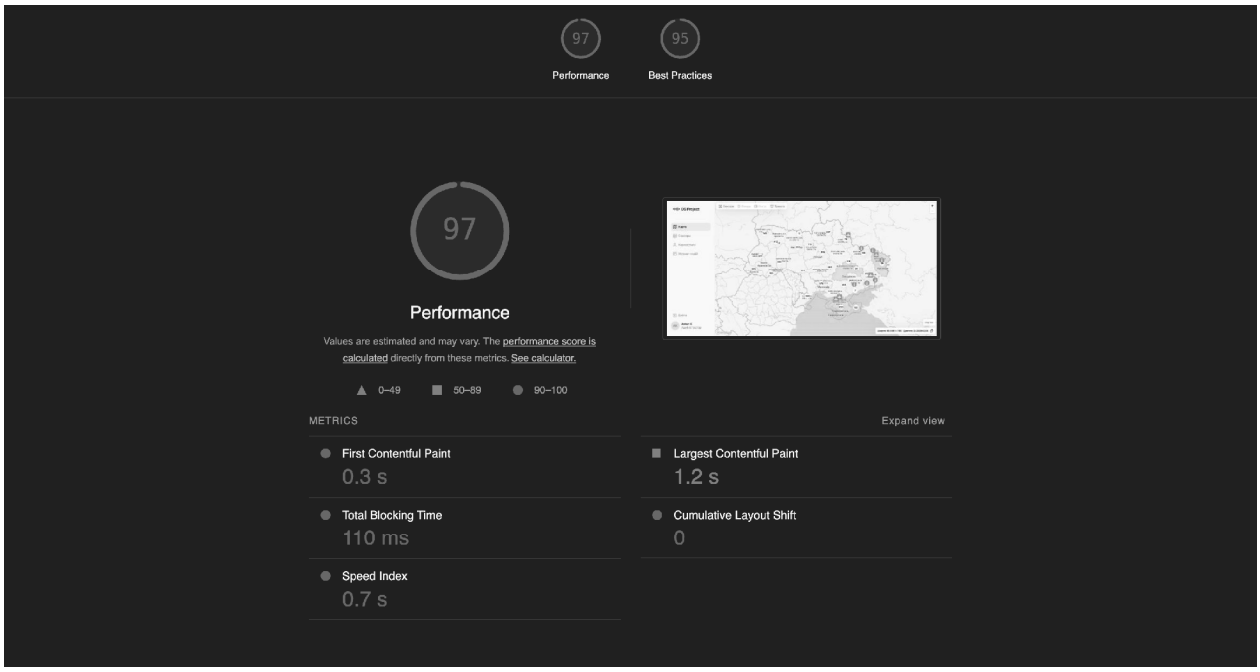

Fig. 4. Web application speed analytics

When testing our software using the Lighthouse tool [20], the following results were obtained, shown in Fig. 4, which demonstrate the high performance and efficiency of the system:

- The first image of the content is displayed in the browser window just 0.3 seconds after the page is loaded. This means that users get quick access to key content.
- The largest image of the content is loaded onto the page in just 1.2 seconds, which increases user comfort and convenience when interacting with the system.
- The total blocking time is 110 milliseconds, which indicates a low number of blocking operations during user interaction with the interface.
- The cumulative layout shift is 0, which means there are no unexpected changes in the page layout during loading.
- The speed index is set at 0.7 seconds, which indicates the speed and efficiency of page loading.

The results confirm that our software performs with high efficiency and provides users with a fast and convenient interface for monitoring air conditions and acoustic sensors.

9. Conclusions

In the context of today's full-scale war in Ukraine, the effective use and display of data from acoustic sensors designed to detect airborne targets is extremely important for ensuring national security and defense capabilities. The developed software creates the necessary infrastructure for effective monitoring and analysis of the air situation and the movement of objects in the air.

The interactive map provided by this system allows to quickly obtain data in real time and display it on a geographic map. This makes it possible to track and identify the movement of drones, missiles, and other airborne targets. Users can interact with the map, analyze data, and make the necessary decisions in real time.

The system has significant potential for further improvement. The focus is on optimizing server performance to reduce resource consumption and increase the response speed to sensor data. At the same time, we plan to expand the functionality, by adding interactive tools for users.

The results of this system can significantly improve the level of security and control in conditions of conflict

and war, contributing to the effective monitoring and protection of important objects and territories. Our work is aimed at ensuring the national security and defense capability of Ukraine.

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Conflict of Interest

The authors state that there are no financial or other potential conflicts regarding this work.

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