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Building a Monitoring System for Bunkering Operations in the Arctic

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Abstract. The Arctic is very rich in hydrocarbons. There is a problem of transportation of extracted minerals since in the Arctic Ocean, and enterprises use only sea transport. There is a high risk of damage to the ship and oil spills, which can cause irreparable damage to the ecosystem of the Arctic. In our work, we are creating a monitoring system onboard the ship. This system should provide continuous monitoring of the situation on the ship.

1. Introduction

A special place in the system of ensuring strategic national interests of the countries of the circumpolar region in the field of economy and transport, environmental protection, innovation, defense, and geopolitics occupy areas adjacent to the Arctic zone [1-2]. The unique resource potential of this region allows, under the condition of the formation of a special system of state regulation of the economy, to ensure dynamic, sustainable development of both the Arctic regions and the country as a whole [3].

Minerals mined in the Arctic, their reserves and projected reserves, explored in the 20th century, make up the bulk of the mineral resource base of the countries of the circumpolar region. The enterprises produce more than 90% of nickel and cobalt, 60% of copper, more than 96% of platinum metals, about 80% of gas and 60% of Russian oil [4]. At the same time, the forecast resources of the listed types of raw materials from other countries of the circumpolar region exceed 70–90% of Russian. For certain types of raw materials (nickel, diamonds, platinum metals, oil, and gas), the Arctic regions of Russia occupy a leading position in the world. The shelf of the Arctic seas, without a doubt, can be considered as a strategic reserve for strengthening the mineral and raw material security of the countries of the circumpolar region [5].

Long-term forecasts of the economic development of the countries of the Subpolar region show that the general forecast estimate of the recoverable hydrocarbon resources of the continental margins of the Arctic Ocean, conducted by academician I.S.Gramberg, is about 110 billion tons of standard fuel [6], which significantly exceeds the reserves of the continental margins of each of the oceans of the Earth. Delivery of the extracted minerals is carried out by the sea on ships [7]. Since such cargo is very dangerous not only when it is ignited, but also in the event of a spill, enterprises must transport it in special tanks on special vessels [8].

Oil spills can lead to disastrous consequences that will have a strong negative impact on the nature of the Arctic (Fig.1)[9]. If you try to group the factors that contribute to the emergence of problems associated with the transportation of such cargo, then we can distinguish the following types of



problems: a group of problems that are affected by the human factor, and a group of problems that are not affected by the human factor.



Figure 1. Consequences of an oil spill in the Arctic.

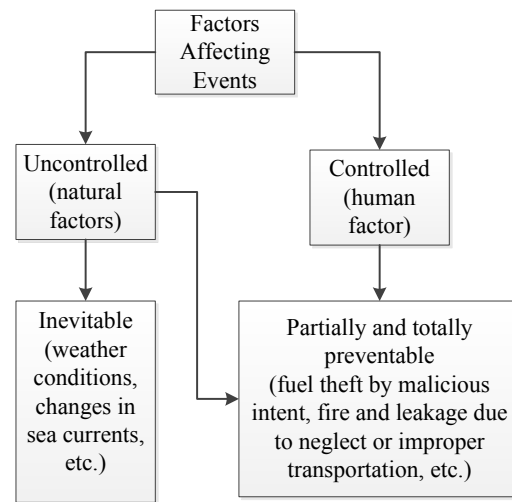


Figure 2. Classification of factors affecting the emergence of problems with the transportation of fuel.

The spill of fuel and its ignition can occur both due to the fault of the ship workers, and due to natural factors, for example, stormy weather, the appearance of fast currents, etc. [10]. As a result, we obtain the following classification of factors (Fig.2).

Uncontrollable factors cannot be affected. In contrast, different methods can influence controlled factors. But since uncontrollable factors consist of inevitable and preventable factors, they can be controlled not so much as by trying to prevent their detrimental consequences. In turn, the impact of all controlled factors can be prevented, perhaps even completely.

Consider the classification in more detail. One of the methods of influence is direct control of the management over the actions of the ship's employees. Being under control, the employee will not attempt to perform any actions (or inaction, which can also lead to irreparable consequences) not specified in his job description. Therefore, theft, fire, and fuel leakage are a preventable group of factors [11].

The remaining group (unavoidable factors) not only cannot be foreseen with absolute accuracy but also cannot be influenced by them [12]. However, it is possible to try to evaluate their intended impact [13]. And based on the evaluation obtained, it is possible to conclude whether it is possible to partially prevent it [14].

Issues of environmental safety of maritime transport are under special control of the governments of countries of the circumpolar region and scientists [15-16].

The above problems determine the strategic direction of research within the framework of the development of the Northern (Arctic) Federal University named after M.V. Lomonosov (NArFU) [17] in the international project Kolarctic CBC 2014-2020: Ice Operations [18]. Project goal: Assistance in the industrial development of the north-eastern territories of the Barents Sea (support for the development of environmentally safe production activities and contribution to the development of projects for offshore platforms for the Arctic territories).

2. Development of technical specifications

The most feasible and effective way is to create an automated monitoring system for the actions of the ship's personnel. Undoubtedly, the fact that the entire control process will be automated already excludes the possibility of attackers to agree with the observers - this is an advantage over the first idea.

Such observation will allow the company to have irrefutable evidence when searching for intruders as a result of theft — everything that happens will be recorded using video cameras on removable media, which in most cases will prevent attempts to steal fuel, since not every attacker decides to steal fuel from a vessel under video surveillance.

However, to fully describe all the advantages and disadvantages of the system, you must first describe the functions performed by it at the enterprise:

- Implementation of video surveillance with the direct recording of the received information on removable media. This feature will allow you to get all the information about the events occurring on the ship. Since, simultaneously with video surveillance, recording to removable media will occur, additional personnel who will remotely monitor everything that happens on the ship are not required.
- Obtaining information on the ship's location by obtaining GPS coordinates from the terminal on the ship with their further recording in the database. Allows you to follow the route of the vessel and find out its location at the moment. In the future, can be used to verify compliance with the actual route specified.
- Obtaining information on the inclusion of pumps for pumping fuel with snapshots (snapshots) corresponding to the given moments, by which one can find out what was happening on the ship at the moment of fuel transfer. We enter this information into a database for further analysis.
- Taking screenshots at regular intervals, regardless of the operation of ship mechanisms.
- Providing the ability to build a route using the received GPS coordinates for a set period (within 1 hour, 6, 12 and 24 hours after manually selected time), viewing received snapshots directly in the program module.

3. Software development

Thus, the entire monitoring system should consist of four modules:

- a module for collecting and transmitting information located on the vessel,
- module for receiving, converting and further transfer of information to the database,
- module for storing information transmitted from the vessel (database),
- a module for presenting information to the user (user application).

Based on the functions that the system will perform, the number of modules that will function within this system should be determined. Let us analyze the following scheme (Fig.3).

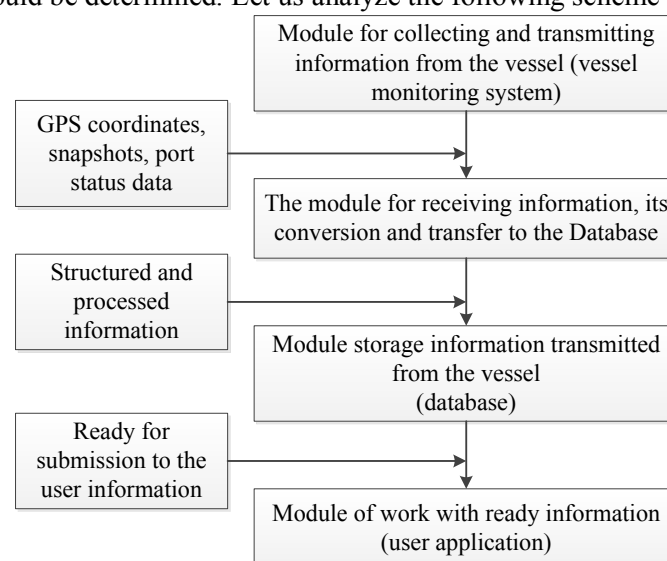


Figure 3. Transferring information from the vessel and converting it into ready for presentation.

The module for collecting and transmitting information from the vessel should include the following elements:

- video surveillance devices (video cameras) and a device for recording data from cameras on removable media (DVR), which will also allow you to receive snapshots when a signal is received to turn on the pumps and send them via a switch via GSM module No.2 to the database;
- a device for obtaining GPS coordinates and sending them from the vessel to a database located in the company's office;
- A device that transmits a signal to turn on the pump to the alarm inputs of the DVR.

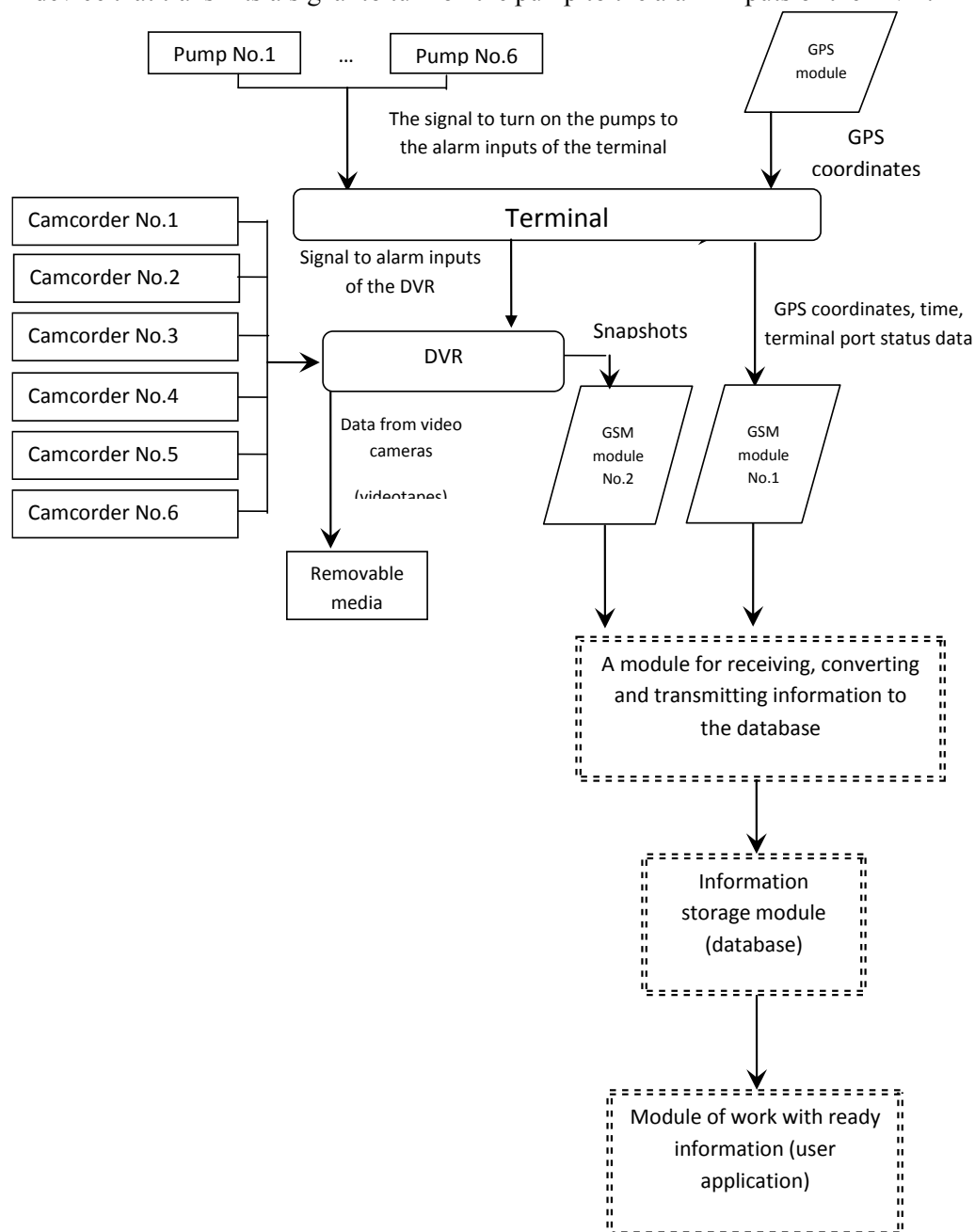


Figure 4. The structure of the module for collecting and transmitting information from the vessel.

We displayed all the elements of the module for collecting and transmitting information from the vessel and the connection between them in Fig.4 (the monitoring system modules, not included in the module for collecting and transmitting information from the vessel, are highlighted).

As can be seen in the diagram, Video Cameras No.1 to No.6 are connected to the DVR, which in turn records the received information on removable media. Also, we connected the Terminal to the electric circuits of pumps No.1 to No.6 to control the voltage reading at the inputs. If the voltage at least one of the inputs is above normal, the Terminal sends a signal to the DVR, which in turn starts creating snapshots and transmitting them via GSM module No.2 to the Module for receiving, converting and transmitting information to the database.

Further, the Module for receiving, converting and further transfer of information to the database, which is an application without GUI (Graphic User Interface), receives information sent by the module to collect and transmit information from the vessel. All information (except snapshots) comes in the form of a string in the decimal number system. The module divides the received string into parts that contain information about the device (its name and IMEI - International Mobile Equipment Identity - International Mobile Equipment Identifier), the state of ports, coordinates, time and stores them in decrypted form in the storage module of information transmitted from the vessel (database) along with snapshots.

Thus, the database will receive information about when the pumps and pictures of everything that was happening at that moment on the vessel, the location of the vessel and the current time were turned on. This information is enough to subsequently verify that someone had leaked fuel at the appointed time or not and when and where it happened.

The module for working with ready-made information is a user application that has a graphical interface and works directly with the database.

The system was developed using the following software products: Visual Studio 2008 C#, MS SQL Server 2008 DBMS [19], Yandex.Maps API [20], Google Static Maps API [21, 22].

Software product development has included several stages of development:

- Selection of equipment for the implementation of the hardware of the vessel monitoring system.
- Database development - "db_Monitor_System".
- Development of a module for receiving, converting, and transmitting information to the database - "Dev_Mon".
- Development of a module for working with ready-made information (user application) - "Get_Pic".

4. Experimental results and discussion

The testing of the software modules of the monitoring system was carried out mainly outside the Bunker office, since it was necessary to check the reliability of the software components, how often the terminal would disconnect from the Dev_Mon module, and what is the reason for such failures, is the user interface convenient for working with Get_Pic module, how correctly the application processes requests, etc.

In the early stages of testing, we found inconvenience when working with the Get_Pic application (Fig.5). Initially, the filter "Display records with pictures" was not provided, while the user needed to sort the records by the presence of pictures. Therefore, this filter was later added to facilitate the work with the query results. Another innovation was the ability to select the type of map that displays the route.

In general, the program modules did not have serious flaws, the presence of which could lead to a system crash: we wrote all the coordinates to the database without loss, all the records were processed correctly, there were no errors in the database records, and the requests in the Get_Pic module worked correctly. Thus, we have completed testing. In the future, we tested the software part of the enterprise.

In the process of creating the system, the function of receiving snapshots from the DVR was implemented and adding them to the db_Monitor_System database. It is responsible for transferring snapshots from the vessel(Fig.6).

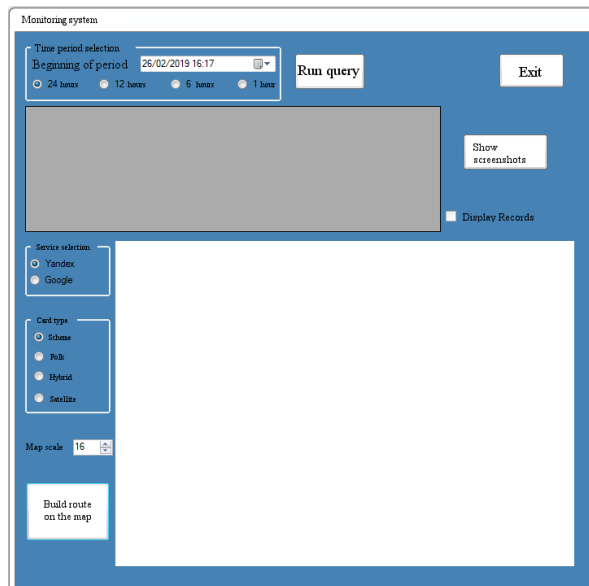


Figure 5. Main program window.

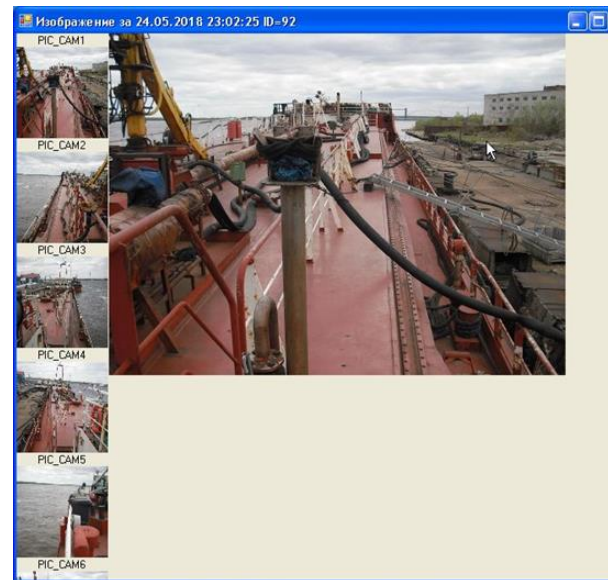


Figure 6. Displaying snapshots when selecting one of them.

Let us highlight the main differences between the idea of creating an automated monitoring system from all the previous ones:

- All monitoring processes are automated;
- There is no possibility of modifying the data sent from the ship by the ship's employees;
- The office receives completely reliable information about the location of the vessel, the time of switching on the pumps, what happened on the deck of the vessel during the operation of the pump;
- Access to the received information can be obtained at any time if you have a user application and access to the Internet;
- The obtained information passes through automated processing and is stored in a structured form, ready for further review and analysis by office workers;
- The whole monitoring process does not require the intervention of outside workers, except for the moments of equipment maintenance and copying information from removable media.

5. Conclusion

The purpose of this work was to optimize the process of monitoring all the work carried out on a remote vehicle. Based on the objectives of this project, we performed the work that resulted in the creation of a system aimed at achieving optimization of the monitoring process of all work performed on a remote vehicle, and, as a result, automation of the work of company employees.

Thus, we have completed all the goals and objectives set for the project at the beginning of the work. Further development of the project involves the improvement of each of the program modules by modifying the working interface, speeding up the program, in particular by reducing the time to access the database, as well as replacing some of the methods used with more complex ones (for example, replacing simple queries with multi-level) and improvement of the function of updating application forms for timely receipt of information from the database.

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