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ROBOT GROUP INTERACTION TECHNOLOGY USING A CLOUD SERVER

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ABSTRACT

This paper presents the technology of interaction of a group of robots using a cloud server. The cloud server is designed to collect information from sensors of robotic equipment and use it to build a map of the workspace for the movement of mobile robots and paving the way. The proposed technology can be combined with the robot control system. The paper gives an example of a constructed map using the sensors of a mobile robot. The method of constructing a map of the space based on the data of odometry and methods for updating previously obtained information is considered. The development of a structural diagram of the cloud storage for the construction of the map of the area was carried out. The structure of the data collection server and the algorithm of the mobile platform in the interaction with the cloud server is proposed.

Keywords: Lidar, ROS, odometry, cloud server.

1. INTRODUCTION

The basic idea behind cloud robotics is that, as a rule, the robot interacts with its environment using its sensors and actuators. In fact, this means that the data received from the sensors must be processed and used to make decisions (as feedback) about the next action of the robot. For tasks requiring real-time operation, processing can be moved to the cloud. This reduces the required processing power of the robot, which can improve the duration of its mobile operation (without recharging) and reduces the cost of the robot. To work in this mode, it is necessary to build a map of the area where the navigation is supposed to be performed in advance.

2. DEVELOPMENT OF A NAVIGATION SYSTEM FOR MAP BUILDING

Autonomous navigation on a predetermined map is one of the possible scenarios for robotic applications, which is of great interest to researchers in the field of robotics. To operate in this mode, it is necessary to build a map of the terrain where navigation is supposed to be performed in advance. In the case where the robot moves only on a flat surface, for example, when moving indoors, the representation of the map can be greatly simplified by considering only the plan of the area.

In this case, the map is represented as a raster 8-bit image, each point (0 – free, 100 – interesting, 1 – unknown) of which encodes the presence of interference in the corresponding area on the map (Figure1).

A map of the entire area is referred to as a global map. To save and load a global map in ROS, there is a map server package which is part of the ROS navigation stack.

The global map is used for localization – determining the position of a job on it. The global map is also used to build a global trajectory for autonomous navigation.

Usually, the requirements for the work to solve the problem of building a map of the terrain are a minimum set of sensors and an automated system for controlling the movement of the work on a given trajectory. The minimum set of sensors required to build a map: wheel encoders (odometers) to estimate the distance covered, necessary to prompt the SLAM algorithm to increase coordinates; sensor distance to obstacles – leaders; IMU (or BINS) optionally may be used as an additional source of information to clarify the data odometry and tilt compensation when driving on an uneven surface.

An example of a possible mobile operation design is shown in Figure2.

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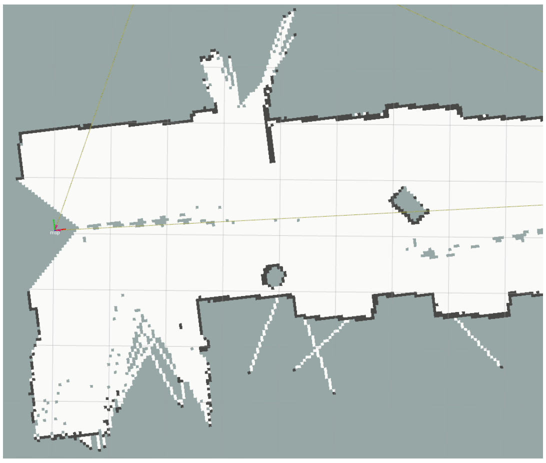

Figure 1. Example of a constructed room map

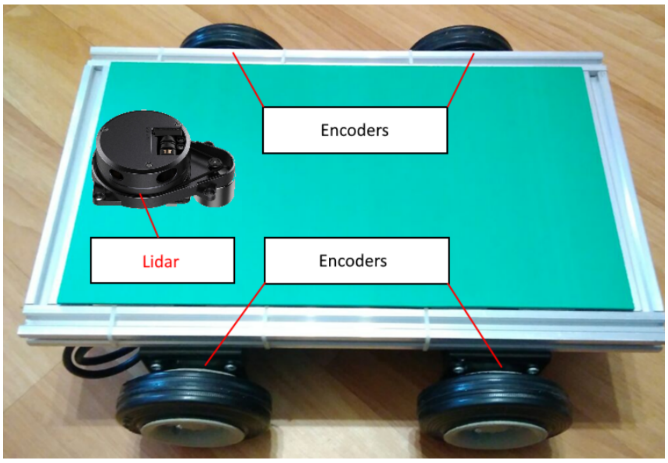

Figure2. Example of a possible mobile robot design

The motion control tasks in this case are three of them: determining the current coordinates of the robot (relative, for example, to its initial position); plotting trajectories (for both well known and unknown map); and specifying the map itself. To construct a flat map of the surrounding space, we have in mind a set of points on the plane bounding insurmountable obstacles.

We use odometers (wheel speed sensors) and a laser scanning rangefinder, which measures the range to obstacles in a plane parallel to the plane of motion of the robot, as our main sensors. As insurmountable obstacles, we understand only the protruding obstacles that fall within the rangefinder's field of view (i.e., they have a height not less than the height of the rangefinder installation).

Therefore, mapping is carried out in three stages: binding the current rangefinder measurements to the map given the current position of the robot; locating the current points on the current map; constructing the map given the new points.

The first task is quite simple. Let the current coordinates of the robot on the plane be expressed by the coordinate transformation of a 3x3 matrix:

$$\begin{pmatrix} \cos(\alpha) & -\sin(\alpha) & x \\ \sin(\alpha) & \cos(\alpha) & y \\ 0 & 0 & 1 \end{pmatrix} \tag{1}$$

here $\alpha$is an angle of rotation of the robot at zero – initial position; x and y – shift of the robot at zero – initial position.

Then the current coordinates of the point measured by the rangefinder will be as follows:

$$\begin{pmatrix} x^{cuy}\cos(\alpha) - y^{cuy}\sin(\alpha) + x \\ x^{cuy}\sin(\alpha) + y^{cuy}\cos(\alpha) + y \\ 1 \end{pmatrix} \tag{2}$$

where x^{cuy} and $y^{cuy}$are the local coordinates of the point measured by the rangefinder.

The second task is to arrange the current points on a known map. It is known that changes may have occurred since the known map was created. It is necessary not only to make these changes to the map, but also not to miss old known obstacles that can be re-measured.

The map is a set of segments in which there are three known points, two end-points and a middle point. The middle point is taken for the stability of the approximation method. To improve accuracy, all points should be memorized, but this will quickly enough cause the control program to require resources beyond the capabilities of any computing system, since the number of points to be handled simultaneously can exceed any reasonable number.

Next, a grid is built on the map, the size of the cells of which should exceed the allowable error. For example, for the case when it is not necessary to solve the problem of passing through a narrowness in advance, the cell size is reasonable to choose half of the width of the robot, possibly extended by the size of the safety zone. A cell is considered occupied if at least one rangefinder measurement falls into it. If the cells are large, enough, these dimensions compensate the inaccuracy of interference coordinates.

A cloud server designed to collect information from sensors of robotic equipment and use it to build a map of the workspace of mobile work. The main requirements to the server are collection of data from sensors; accumulation of the received information in the built-in database management system, display of actual data in graphic or text form, automatic updating of information; organization of access to the server through a dedicated interface, display of graphic information of the workspace map on any device that has network access and a graphic display.

Figure 3 shows the architecture of interaction between the server and the developed sensors of the mobile robot.

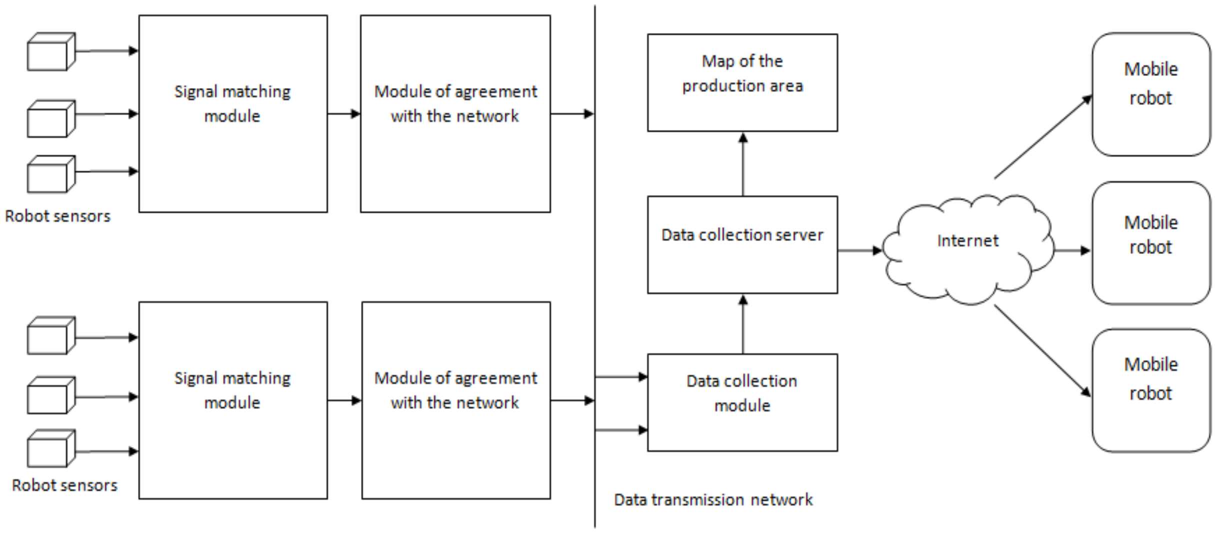

Figure 3. Architecture of interaction between the server and sensors of the mobile robot

To solve the problem, the data collection server must have the following software modules: – database management system; REST-server; service for preparation of graphic information; service for interaction with the network using REST-technology. Service for interaction with the network receives requests using REST-technology. Software controllers process the requests and distribute the received information to the required directions. REST is an architectural style of interaction between components of a distributed application in a network. REST is a consistent set of rules considered when designing a distributed system. A single interaction interface allows different devices to communicate with the data collection server. The received data are distributed in the database tables according to the mobile equipment from whose sensors they were received.

At the customer's request, the service of preparing the graphical information finds the necessary information in the database and prepares for display the necessary content to build a map of the area.

The control system of the mobile robot performs the orientation of the device depending on its current position and data about the map downloaded from the cloud server terrain.

Figure 4 shows the algorithm of the mobile robot path finding module using the disturbance location data obtained from the cloud server.

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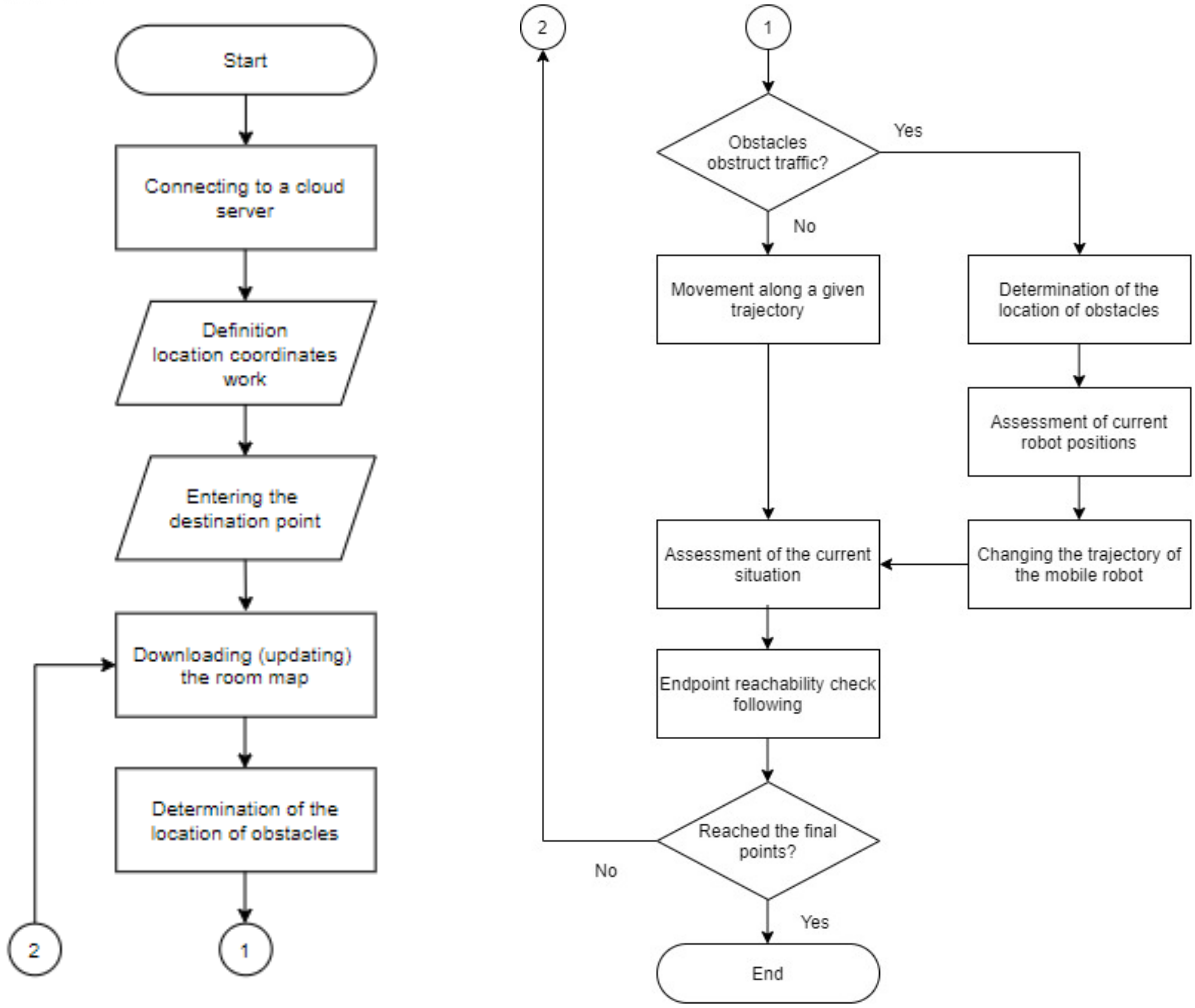

Figure 4. Control algorithm for a mobile robot using LiDAR technology

The data coming from the cloud server allows the navigation system to optimize the robot's trajectory and correct it if obstacles prevent it from moving. The motion control process ends when the robot reaches the target point.

As it moves, this robot, like any other robot, transmits the coordinates of obstacles found, as well as the coordinates of its location, to a cloud server so that other mobile platforms can quickly rearrange their trajectory.

The data to be stored on the cloud server comes from various sensors placed on the mobile work. Such sensors can be: a scanning laser device for measuring distance to interference in a wide field of view (LiDAR); wheel rotation sensor; acceleration sensor; magnetic sensor (digital compass).

Each of the above sensors has a specific set of data that makes up a packet of information to the server. Let's look at an example of a data packet that is generated from Lidar and transmitted to the server.

Figure 5 shows the contents of the data packet transfer from LiDAR to the data acquisition unit.

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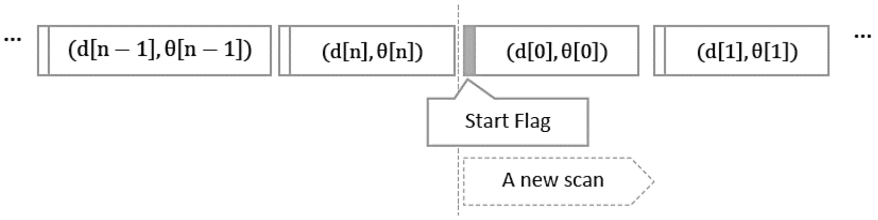

Figure 5. Format for transmitting information from LiDAR to the data collection unit

The Lidar data acquisition unit receives information about the objects surrounding the mobile work with a laser scanner. Based on the received data a terrain map is created by the corresponding unit. The decision-making block analyzes the received information and based on this information forms commands for execution by the control unit. After that, the control unit exerts control action on the propulsion mechanisms for further movement of the work in space.

In each field of the frame, the following information is transmitted: the current measured distance between the rotating sensor and the interference point; the current angle of rotation of the distance measurement sensor; the measurement accuracy; the sign of the beginning of a new scanning. After receiving the above information from the laser scanner, the data acquisition unit transmits the data to the terrain mapping unit. This unit is based on the SLAM development.

Simultaneous navigation and mapping method (SLAM) is a concept that links two independent processes in a continuous cycle of consecutive calculations, in which the results of one process are involved in the calculations of the other process.

To verify the proposed algorithm for working with cloud storage, a program was developed that performs the following functions: displaying the list of mobile devices registered on the server; displaying the room plan; generating a terrain map based on data from the cloud storage; accumulating information about the environment of the mobile platform to build a terrain map.

The main window of the program is shown in Figure 6. The interface consists of the list of mobile robots registered on the server (left area of the program), and the work area, which allows the operator to perform research related to the construction of the room map based on data from sensors (right area of the program). In the workspace there is a TabPage component with three tabs. The first tab shows a test layout of the room. There are various objects in the room, which must be considered when moving the robot. For a mobile robot entering an unfamiliar room, its plan will be completely undefined. The first step is to explore the cordoned-off area using the built-in sensors.

The program implements a simulation of the space scanning process. In this mode, consecutive waves of searching and determining the coordinates of the interference location in the sensor area are run (Figure 7).

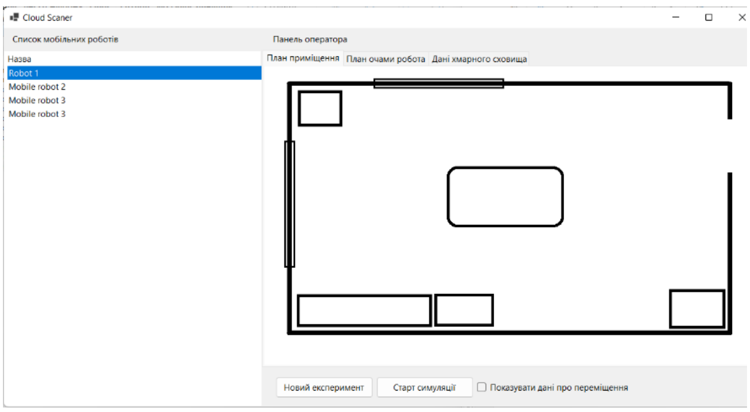

Figure 6. Main window program interface

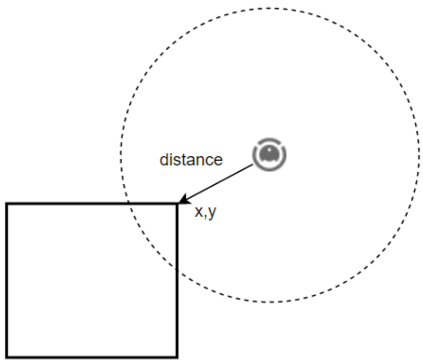

Figure 7. Determining the distance to an obstacle

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From the example, you can see that the scanning distance increases sequentially from the minimum to the maximum value. In the process of scanning, the angle of rotation of the sensor changes sequentially from zero to 360 degrees. If for the given angle an obstacle is found, the distance to it and the angle of rotation are memorized. At the next scanning radius, this angle is no longer used to reduce the time of this procedure.

The result of the scanning is a set of points in the format:

50-{X=815,Y=84};270-{X=816,Y=87};320-{X=815,Y=76};100-{X=815,Y=72};150-{X=815,Y=56};30-{X=788,Y=32};80-{X=773,Y=32};250-{X=793,Y=33};300-{X=778,Y=32};350-{X=761,Y=32};130-{X=755,Y=32};200-{X=813,Y=32};180-{X=734,Y=33};230-{X=702,Y=33};

Figure 8 shows an example of visualization of the obtained data. The described scanning principle is completely identical to the real work of a mobile robot. All data obtained after each interference search cycle is stored in the cloud storage database. After completing the phase of room exploration and collecting all the interference data in the sensor coverage area, we get a cloud of points described by the workspace. Figure 9 shows an example of visualization of the point cloud.

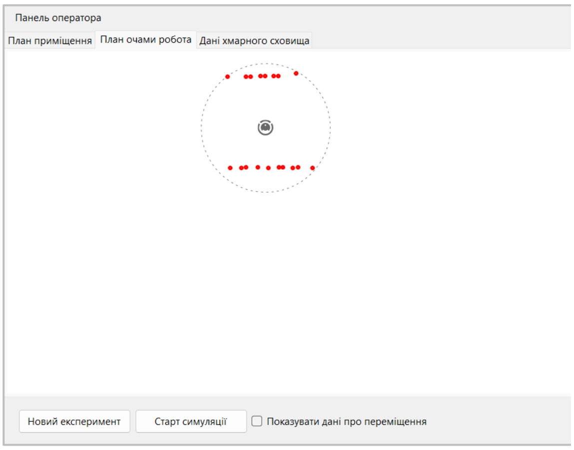

Figure 8. Example of space scanning by a robot

Figure 9. Example of room map visualization

The developed program allows to view the point clouds for each mobile device registered on the cloud server. Appropriate models are used to access the data.
Data model for the Profile entity:

```
publicclass Profile Model
  {
publicstringID_Device { get; set; }
publicstringName { get; set; }
publicstringStatus { get; set; }
  }
```

Data model for the Measureentity:

```
publicclassMeasureModel
  {
publicintID_Measure { get; set; }
publicstringDateMeasure { get; set; }
publicstringTimeMeasure { get; set; }
publiclongDateTimeMeasure { get; set; }
publicstringDataLidar { get; set; }
publicintID_Device { get; set; }
publicintDevice_X { get; set; }
```

```
publicintDevice_Y { get; set; }
  }
```

Data model for the Place entity:

```
publicclassPlaceModel
  {
publicintID_Place { get; set; }
publicintID_Device { get; set; }
publicintDevice_X { get; set; }
publicintDevice_Y { get; set; }
publiclongDateTimePlace { get; set; }
  }
```

The developed program also provides the ability to store all points of the trajectory of the mobile robot. Further, in the course of the study it is possible to see the dynamics of the work along the room, taking into account all points where the scanning took place.

3. CONCLUSION

Thus, this paper presents the results of research in the field of navigation of mobile robots, the proposed technology of navigation of a group of robots using a cloud service with the use of a single server designed to collect information from sensors of robotic equipment and use it to build a map of the working space. An example of a constructed map of a room using sensors of a mobile robot is given. An example of a possible design of a mobile workplace used to build a map of the area is given. The structural diagram of the cloud data storage for the construction of the terrain map is developed. The structure of the data collection server is developed and the algorithm of the mobile platform in interaction with the cloud server is proposed. The developed application performs the following functions: displaying the list of mobile devices registered on the server; displaying the room plan; generating the ground map based on the data from the cloud storage; accumulating information about the environment of the mobile platform to build a ground map.

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