Modeling USAR maps for the collection of information on the state of the environment

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***Abstract*— There is a problem associated with various natural and man-made emergencies. The consequences of which can be colossal destruction in densely populated territories. Therefore, USAR teams, which include rescue robots, need to act quickly. However, due to the unpredictability of the situation, rescuers are faced with a number of difficulties due to which expensive equipment can suffer. To prevent the latter and optimize the work of robots, it is necessary to conduct testing in an environment close to reality. For many reasons, this cannot be done in real life, so there is a need to recreate the danger situations in format USAR in a simulation environment, designed to develop algorithms for the interaction of robots with a simulated environment.**

***Keywords*— robotics, urban search and rescue, USAR, ROS, Gazebo.**

I. Introduction

During various disasters, the primary task in the affected area is to minimize the detrimental impact of emergency sources on the environment and the health of people in the danger zone. In order to respond quickly and effectively to incidents, it is necessary to introduce the development of the robotic industry at the planning and investigation stage of the area during rescue operations. The focus of robotics engaged in rescue activities is the urban search and rescue (USAR) [1]. Teamwork of robots and human rescuers will reduce the detrimental effect of atmospheric pollution on people working in hot zones and simplify the search for victims who have fallen into hard-to-reach places, the voids of destroyed buildings during earthquakes [2, 3 and 4]. Air robots, various airship-drones, quadcopters, allow you to get up to date information about the affected area [5]. Underwater and surface water equipment allows you to analyze the state of the water surface and the bottom of the water area for the presence of sources of pollution or other hazards [6].

Nevertheless, robots are also affected by the problem area. That can cause damage to the equipment of the robot or the robot as a whole. Then such incidents happen in real conditions can lead to inhibition of the conduct of search and rescue activities, and at large scales to the disruption of the operation. It should plan the route of robots to bypass dangerous or infected places [7]. With the high cost of robots, the exit from the working condition of the equipment will lead to additional financial losses [8]. To avoid such unpleasant situations, it is necessary to conduct a large number of test operations with constructing locations with possible aspects of the USAR scenario. Such works will be very labor-intensive, and the territories selected as test sites will need to be cleaned and brought to a stable state after tests, which will also lead to high costs. For this reason, it has become necessary to model such locations in simulation environments, which will speed up test work and reduce financial costs.

There are ready-made solutions, simulators for USAR tasks. So, the simulator was developed using the Epic Games Unreal game development technology. Development using commercial solutions EGU, allows you to quickly develop a modeling environment for the tasks, in particular USAR, with the addition of the necessary functions of the created environment. The Unreal Tournament and Gamebots API game engine, together with the infrastructure agent RETSINA, created a simulation that will provide researchers with a high-quality, inexpensive test bench for assessing the performance of remote-controlled robots in an urban search and rescue environment [9].

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This article describes a map generator based on the Gazebo simulator and the ROS platform. Section 2 describes possible levels of contamination in the hot zone and features of the simulated environment. Section 3 describes the map generator and building modeling in the gazebo. Section 4 summarizes the requirements for creating layers of pollution. Section 5 describes the levels of contamination generated by ROS. Section 6 describes the launch of a test simulator with input and output parameters. Section 7 concludes the discussion on further ways to improve the generated software.

II. POSSIBLE AREA POLLUTION IN TYPICAL USAR SCENARIOS

In USAR, the work areas are divided into three types: cold zone, heat zone, hot zone. The first two zones are not dangerous, there provide first aid to the victims, the work of psychologists with the victims and relatives of people who are on the territory of the emergency, those who are not found, and media reporting. The hot zone is directly the area that has been affected by natural disasters or man-made accidents. Next will be considered the features and problems faced by the population that has got into the area from the potential danger to life, rescue teams conducting search and rescue operations and robots being introduced into search activities [10].

There are a lot of potential dangers in the hot zone. The main part of them may not affect the victims, but in turn they bring tremendous problems to rescuers and robots in conducting rescue activities. For example, interference in connection with the robot or lack of communication in certain areas, making it difficult to obtain relevant information about the robot, its location and communication with the group [11]. Abundant precipitations that interfere with the correct image from cameras and laser sensors, which allow the robot to be oriented on the ground, there is also a risk of damage to elements exposed to the ingress of liquid [12]. And much more, Table I presents an extended list of pollution layers and terrain features with a description of the impact on the robot, sensors with which these effects can be recorded and the layer, buildings, or if there is such an opportunity, such models do not have sufficient detail to conduct tests close to reality.

TABLE I. ENVIRONMENTAL PARAMETERS IN USAR CONDITIONS

Parameter	***Description***	***Sensor***	***Layer***
Noise	Affects the acquisition of information from microphones [2], [10]	Microphone, vibration sensor, noise sensor	Sound
Precipitation	Worsening the quality of shooting cameras, with strong winds and temperatures around zero Celsius can lead to a complete blockage of camera visibility due to the lens being covered with a snow crust [10]	Camera, humidity sensor	Weather, Water
Hazardous gases	Gases can lead to serious consequences, so if large amounts of combustible gases are accumulated in the room when the robot gets there and if the robot has DC drives that cause sparking during operation, such a combination of factors can lead to an explosion [2], [10]	Gas leak detection sensor	Air
Interference in communication	Loss of communication with the robot becomes a big problem when a robot enters areas of the area where a person cannot enter, this completely removes the robot from the operation [10]	Communication module	Connection
Unstable structures	After strong earthquakes, most of the houses are destroyed, and their overlap can hang at rest due to the support of other parts of the destroyed houses, when driving a robot through similar structures, it can set the structures in motion, which would entail collapses with further burial of the robot [10]	Camera, surface scanner	Map
Narrow spaces	Sometimes there are situations when the robot finds places where the robot cannot enter or, on the contrary, leave due to the narrowing of the space [10]	Camera, laser space scanner	Map
Unstable surface	During earthquakes, underground voids or large chasms with steep descent may appear, which in the first case will result in the robot being in an impossible position with its blockage, and in the second case falling from a great height with joint destruction of equipment [10]	Camera, surface scanner	Map
Icing	Icing the surface leads to a deterioration in the adhesion of the wheels of the robot to the surface [10]	Thermometer, laser sensors	Map
Radiation	This type of danger includes a whole range of contamination levels, particle radiation increases the temperature, therefore radiation can be identified as a separate layer [3]	Geiger counter	Radiation
High humidity	Humidity also contributes to increased corrosion of the casing of robots [10]	Humidity sensor	Air, Water
Dust	Dust leads to interference in communication and deterioration in work of laser sensors and cameras [2], [11], [12]	Camera	Air
Flooded spaces	During heavy precipitation and melting of snow, large areas are subject to flooding, which does not allow the use of ground robots. If the robot falls into the flooded areas, it can lead to breakdowns.	Humidity sensor, camera	Map, Water

Parameter	*Description*	*Sensor*	*Layer*
Critical temperatures	At high values of temperature, the robot can burn out, and at low values, the body can become fragile and the power supply system will quickly fail [2], [3]	Thermometer, infrared scanner	Temperature
Strong wind	Strong gusts of wind can destabilize the robot, with small masses of robots' gusts of wind can throw them	Microphone, noise sensor	Air
Fog	Fog can be considered as one of the types of high humidity with an additional deterioration in visibility	Humidity sensor, laser sensors	Air
Smoke	In case of fires, a large amount of smoke is emitted, which can be a problem for video recording and sensor operation [2], [12]	Smoke sensor	Air
Lack of lighting	In the absence of lighting, the quality of shooting is deteriorating	Light sensor	Air, Map
Trash	Trash can hide in itself the sources of various hazards given in this list [2], [12]	Camera	Map

III. CREATING RESIDENTIAL AREAS IN GAZEBO

Works on the creation of the world were made on the platform of the Gazebo simulator. There are models of whole houses and with destruction in the simulator. On the basis of them, you can create maps simulating destruction in a small urban area, but these models are not suitable for working with robots due to the inability of the robot to travel inside buildings, or if there is such an opportunity, such models do not have sufficient detail to conduct tests close to reality. Due to the lack of ready-made building models suitable for creating authentic maps of real terrain, it was decided to create their own buildings.

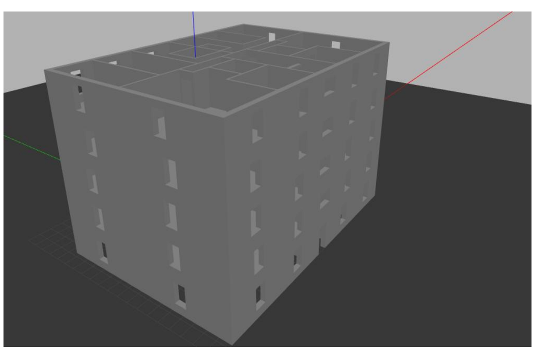

Fig. 1. Example of a constructed five-story house.

To create a model used the editor of buildings, built-in Gazebo [13]. For the simulation, one of the most popular buildings in the Russian Federation was chosen: a panel house built in the sixtieth years of the 20th century. There are many series and modifications of the construction projects of that time, differing in the number of entrances and floors. Of these, the main features and features of the internal structure were selected. In the process, for the convenience of creating variations of the location of buildings, a single-entry house with a different number of floors was modeled. In addition, large labyrinths with a multitude of rooms and stairs were created for test launches, such houses are not able to convey all the characteristics of residential development, but it is convenient to use them to develop various algorithms for maneuvering and passing through difficult places. In the process of testing with the model of the robot, the appropriate parameters of the stairs were selected for optimal passage to the upper floors of buildings, the optimal width of the passages so that the robot could pass through them in ideal conditions. Below is an example of a described house with five floors (Fig. 1).

A plugin for the world of Gazebo was written. A large number of test runs were carried out to select the optimal number of buildings located on the map. The maximum number of buildings for comfortable work was 4 houses (Fig. 1) and 7 test labyrinths. Such a number of buildings is maximum for normal testing of algorithms for collecting information with a robot model. Further, decorative elements were added to the world that serve as additional conditions, power lines, trees, models, simulating trash, and many others. So, (Fig. 2) is an example of a plug-in in the world of Gazebo.

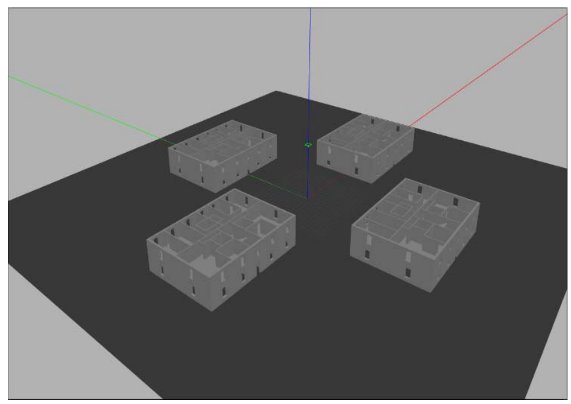

Fig. 2. The result of building a plug-in for placing models of two-story cottages.

IV. REQUIREMENTS FOR MODELING POLUTION LAYERS AND ENVIRONMENT FEATURES

After analysis, data on the types of pollution and the characteristics of the area in which rescue operations are carried out are collected. Because of the analysis, the following requirements were highlighted, some were implemented in practice.

1) Landscape

The lanscape is the first layer of the entire map, with respect to its features the following layers will line up. This layer should simulate the surface of the earth depending on the type of simulated map. For example, during earthquakes, it is necessary to simulate faults in the ground, cracks, cliffs, changes in surface homogeneity. In addition to simulating the visual component, the landscape must transmit the physical properties of the surface to the robot's transmission. Imitation of slipping with icy and wet surfaces, burying in the ground with a viscous surface, immersion when ingested in a marshy and any other water surface [2, 10].

2) Buildings

On the generated landscape is the level of buildings. Buildings should simulate urban development, reflect the appropriate environmental conditions. Buildings must be modeled both inside and out. The destruction must be not only on the facades of buildings, but also inside. Buildings should not transmit light in cases where the building is not damaged and has no through defects through which light can pass.

In the zones of destruction, it is necessary to work out the places with unstable structures on the internal overlaps of buildings, getting into which the robot should be blocked with further blocking of the control of the robot. Also, on the map it is necessary to provide areas with high rises in buildings where robots can enter, but when attempting such an action, they should roll over with a far inability to control [1, 10].

3) Light

On the map, the total light should be regulated, thus it is possible to change the day to night. The buildings should also have light sources, if they are located in untouched buildings or parts of them at the time of generation of buildings. Indoors it is necessary to realize the lighting from the sunlight from the windows.

The map should contain indirect sources of light, light from the fire. The light from the fire should be in several spectra (red, yellow, shades of orange).

The absence of light will greatly complicate the orientation of robots in space. This requirement will allow testing robots in complicated situations.

4) Radiation

Radiation affects a large number of factors: air pollution by radiation of radioactive isotope particles, human exposure, dielectric conductivity, oxidation of metal fragments of boards installed in the equipment of the robot. It should be possible to regulate the level of radioactive contamination. There should be sources of radiation with a physical impact on the robot, after the accumulation of a certain value of radiation, the equipment of the robot must be turned off.

The accumulated radiation should depend on the time the robot is in the area of exposure of the radiation source and the distance from the radiation source and be calculated during the (virtual) testing. Instant radiation is an indicator of a one-time impact on a robot, and it should be transmitted to a robot [3, 10].

5) Temperature

Temperature is an important factor in USAR; it affects almost all aspects of work: the operating time of robots, the coupling of the transmission from the surface, the structure of objects. The temperature must be variable and transmit the readings to the robot, depending on the region where the robot is located. Extremely high and extremely low temperature areas should be modeled, which would emit hot spots and low gas leaks. These fluctuations should be recorded to build maps of sources of pollution.

6) Weather

We can identify the main problems associated with weather conditions: rain and snow. Rain and snow interfere with video fixation, flood equipment, take it out of service, or cause equipment to work incorrectly. Snow may be in the form of hail, with the loss of this type of precipitation, there should be possible damage to the hull and the onboard sensors. It is necessary to model the conditions of precipitation with the described criteria of distortion and physical impact.

Weather conditions also include strong wind. This type of impact on equipment should be a problem for air robots, their sustainable management, the possibility of exploring the territory of the map, orientation in space. Strong gusts should take down light ground robots to the side and turn them around. It is necessary to realize the effect of wind on microphones, to create noise. A general wind direction should be created on the map with attenuations in areas behind large spaces, for example, behind houses [10].

V. CREATED POLLUTION LAYERS

In Gazebo, it is not possible to integrate the layers described in Table 1. The implementation of the described ones was created based on the interaction of the nodes in the ROS framework.

1) Temperature layer

In Gazebo version 9, there is an atmosphere with temperature and atmospheric pressure readings. This is a very useful function, but this innovation does not allow setting environmental parameters at a single point, possible changes in temperature data are applied immediately to the entire map. For optimal distribution of temperature data, a node was created in the ROS. This node sets from up to five points simulating the centers of ignition with different indices of ignition power. Depending on the intensity of the indicator of the source, is set the temperature at the epicenter and the radius of impact, with a decrease in values, is proportional to the distance to the source. Exposure points may intersect. When a robot hits the area of influence fire, the distances to all points are calculated, the most fitting is taken and the temperature is calculated. When the robot leaves the zone of influence, the temperature decreases, and if the robot is located outside the influence of all sources, the temperature assumes a static value of 20 degrees Celsius. This change indicates that the robot is out of the influence of the hazardous area of ignition and is not threatened with the danger of destruction.

2) Radiation layer

The second layer realized was radiation. This layer has a similar structure. The position of the radiation center is randomly located on the map. The initial value is taken randomly, which corresponds to the intensity of the source.

$$D = P * t / R2 \qquad (1)$$

The values of the indicator are calculated according to (1), where P - the radiation intensity (Sv/h), t - the time spent in the affected area (h), R - the distance to the epicenter (m), and D - the calculated dose (Sv).

VI. SIMULATIONS IN GAZEBO

To run the simulator, you must prepare the space for its successful launch. In the directory from which the launch occurs, the export of the created models of tasks is recorded. A plugin file is pre-prepared where the positions of the simulation objects are written. The prepared file is compiled, after which the simulation environment is ready to run.

The launch of the simulator takes place using the written launch file. It contains the launch files of the robot on specific coordinates; the launch parameters of the robot contain a link to the generated map. In addition, the startup file contains temperature, radiation, and a navigation node.

The robot control node accumulates environmental data and writes it to a json file. The recording is made when the robot reaches the specified coordinates, fixes the position, x and y coordinates, and radiation temperature data (Fig. 3).


```
{
  "y": -5.007594623110426,
  "x": -10.012105135544823,
  "rad": 1.0668262243270874,
  "temp": 65.65321350097656
},
```


Fig. 3 Record from the log of the environment.

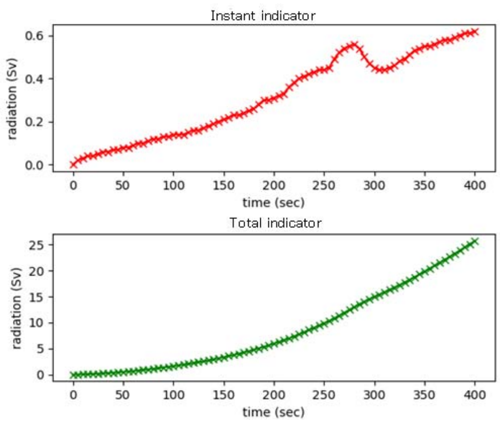

Fig. 4 Graph of instantaneous and accumulated radiation, for which the robot was destroyed.

The collected data is used to monitor the status of the robot in the simulation and its shutdown when the permissible norm is exceeded. So (Fig. 4) graphs of radiation indices are depicted, of which the robot failed and turned off.

According to the journal, the map is formed with temperature indicators (Fig. 5) (Fig. 6), points are marked with four colors depending on the danger: green is a safe zone, yellow is higher than normal, orange is a danger to people, red represents danger to the robot.

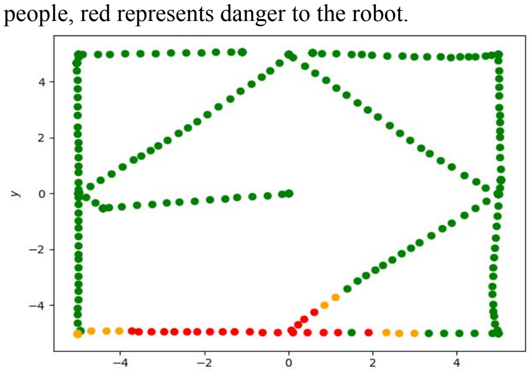

Fig. 5 Indicators of temperature sensors during the destruction of the robot.

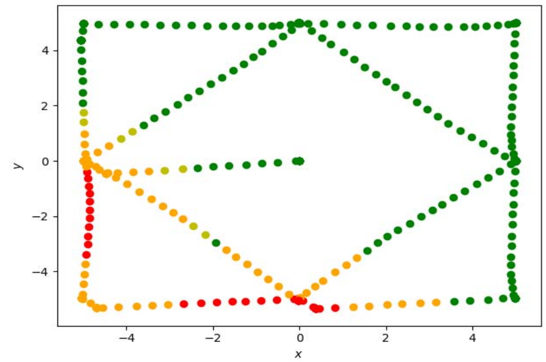

Fig. 6 Indicators of temperature sensors when the robot passes the specified route.

A large number of test runs were conducted, during which a slowdown in the operation of the simulator with a large number of objects in the environment was found. Therefore, for optimal operation of the maneuvering and card collection algorithms, the content of the world has been simplified. So (Fig. 7) - on the map with a large number of models, when launching such a card with a robot, the problems described above arose, an example of a simplified map is shown in (Fig. 8). Husky robot was used to test the maneuvering algorithm (Fig. 9) [14].

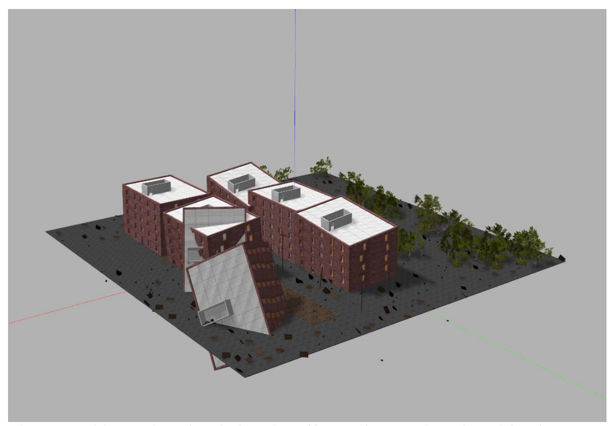

Fig. 7 World Gazebo, simulating the effects of an earthquake with a large number of models.

Experiments were performed on an Intel® Core i5-3210M 2.50 GHz PC with 6 GB DDR3 RAM and an AMD Radeon HD 7500M / 7600M Series 2 GB graphics card. It was used ROS Melodic [15] and the seventh version of the simulator Gazebo [16]. The modified spline-based algorithm [17] previously developed was used as a path-planning algorithm. The launches were carried out on different routes composed of a different number of points of visit, with the passage of ten points with the return to the original position takes 15 minutes. This path has the shape of a square. If the path is adjusted to a more detailed passage like a figure (Fig. 6), then it takes about 28 minutes.

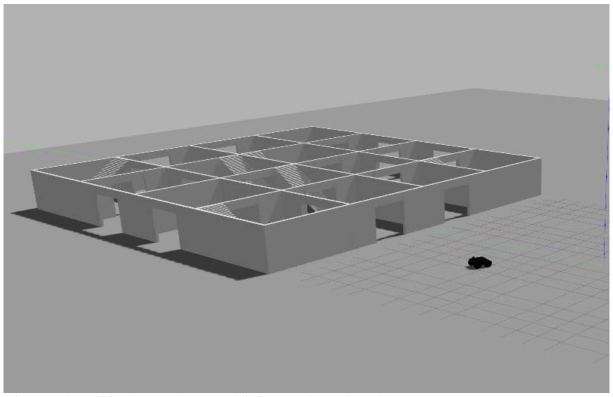

Fig. 8 Simplified Gazebo world for testing algorithms

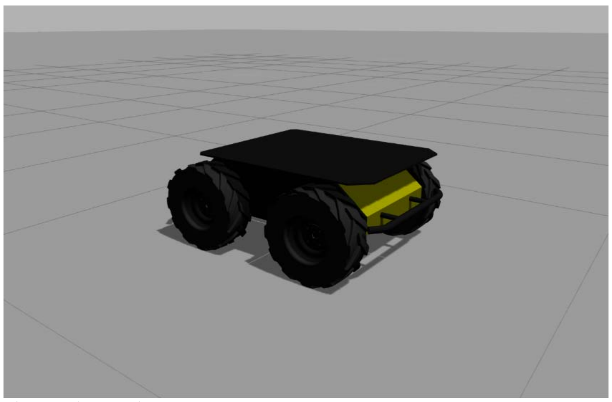

Fig. 9 Robot Husky

VII. CONCLUSIONS AND FUTURE WORK

Today, the issue of avoiding colossal losses in connection with an increase in the number of tragic cases of various catastrophes is very acute. Develop in the field of robotics, namely the urban search and rescue robotics, helps to simplify the work carried out in emergencies.

This article describes the development of a module for the Gazebo simulator, which simplifies further developments of the USAR direction in robotics [18]. In the future, this module will be improved, new layers of pollution will be added, the algorithm will be developed for planning and SLAM tasks [19, 20], for collecting data about indicators in the simulation, for the optimal passage of the maps created.

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