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# DESIGN OF ROBOTIC ASSISTANT FOR SEARCH AND RESCUE OPERATIONS

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*The need for search and rescue (SAR) operations arises in various situations: natural disasters such as earthquakes, hurricanes, floods or avalanches, accidents, etc. It is known that the large volume and diversity of the identified area, the limited view, dangerous conditions and the presence of victims in remote or hard-to-reach places complicate such work. The use of advanced technologies such as robotics in improving the efficiency of search and rescue operations to solve problems in these cases allows us to obtain rational solutions.*

*A robotic assistant for search and rescue operations has been developed, a 3D model has been developed. The robot is controlled autonomously or remotely, overcome difficult terrain, collect data and perform tasks that contribute to the search and rescue process. Internet of Things devices and sensors interact over the network, allowing you to collect, analyze and share data in real time. The Arduino board was chosen to create the project. The device circuit was assembled and the operation of the sensors was combined. The device used an ultrasonic sensor, a camera, LED lamps and a speaker for the sound of a siren. The robot assistant works in both offline and manual modes. The device is controlled via a web interface, and the video received by the camera is provided in real time. The wheels of the device can move over any terrain, and the device is designed so that it can move on both sides (under and over).*

***Keywords:*** *Smart cities; robotic assistant; Arduino; M2M; sensors.*

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# ІЗДЕСТІРУ-ҚҰТҚАРУ ЖҰМЫСТАРЫНА АРНАЛҒАН РОБОТ-КӨМЕКШІНІ ЖОБАЛАУ

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*Іздестіру-құтқару жұмыстарын жүргізу қажеттілігі әр түрлі жағдайларда туындайды: жер сілкінісі, дауыл, су тасқыны немесе қар көшкіні, апаттар және т.б. сияқты табиғи апаттар. Анықталған аумақтың үлкен көлемі мен әртүрлілігі, шектеулі көрінісі, қауіпті жағдайлары және зардап шеккендердің шалғай немесе жету қиын жерлерде болуы мұндай жұмысты қиындататыны белгілі. Осы жағдайларда проблемаларды шешу үшін іздестіру-құтқару жұмыстарының тиімділігін арттыруда робототехника сияқты озық технологияларды қолдану ұтымды шешімдер алуға мүмкіндік береді.*

*Іздестіру-құтқару жұмыстарының роботтық көмекшісі – 3D моделі жасалды. Робот автономды немесе қашықтан басқарылады, қиын жерлерді еңсереді, деректерді жинайды және іздеу-құтқару процесіне ықпал ететін тапсырмаларды орындайды. Интернет Заттары құрылғылары мен сенсорлары желі арқылы өзара әрекеттесіп, нақты уақыт режимінде деректерді жинауға, талдауға және бөлісуге мүмкіндік береді. Жобаны жасау үшін Arduino тақтасы таңдалды. Құрылғы тізбегі құрастырылып, сенсорлардың жұмысы біріктірілді. Құрылғы сиренаның дыбысы үшін ультрадыбыстық сенсорды, камераны, Жарықдиодты шамдарды және динамикті пайдаланды. Робот көмекшісі офлайн режимінде де, қолмен де жұмыс істейді. Құрылғы веб-интерфейс арқылы басқарылады, ал камера қабылдаған бейне нақты уақыт режимінде беріледі. Құрылғының дөңгелектері кез келген рельефте қозғала алады, ал құрылғы екі жағынан (астынан және үстінен) қозғала алатындай етіп жасалған.*

***Түйін сөздер:*** *ақылды қалалар; робот көмекшісі; Arduino; M2M; сенсорлар.*

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# РАЗРАБОТКА РОБОТА-АССИСТЕНТА ДЛЯ ПОИСКОВО-СПАСАТЕЛЬНЫХ ОПЕРАЦИЙ

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*Необходимость в проведении поисково-спасательных операций (SAR) возникает в различных ситуациях: стихийных бедствиях, таких как землетрясения, ураганы, наводнения или лавины, несчастных случаях и т.д. Известно, что большой объем и разнообразие выявленной территории, ограниченный обзор, опасные условия и присутствие пострадавших в отдаленных или труднодоступных местах усложняют такую работу. Использование передовых технологий, таких как робототехника, для повышения эффективности поисково-спасательных операций для решения проблем в этих случаях позволяет нам получать рациональные решения.*

*Разработан робот-ассистент для поисково-спасательных операций, разработана 3D-модель. Робот управляется автономно или дистанционно, преодолевает сложную местность, собирает данные и выполняет задачи, которые способствуют поисково-спасательному процессу. Устройства и датчики Интернета вещей взаимодействуют по сети, позволяя собирать, анализировать и обмениваться данными в режиме реального времени. Для создания проекта была выбрана плата Arduino. Была собрана схема устройства и объединена работа датчиков. В устройстве использовались ультразвуковой датчик, камера, светодиодные лампы и динамик для подачи звука сирены. Робот-ассистент работает как в автономном, так и в ручном режимах. Управление устройством осуществляется через веб-интерфейс, а видео, получаемое камерой, предоставляется в режиме реального времени. Колеса устройства могут передвигаться по любой местности, а само устройство сконструировано таким образом, что может перемещаться в обе стороны (под и над).*

***Ключевые слова:** умные города, робот-ассистент, Arduino, M2M, датчики.*

**Introduction.** The Internet of Things (IoT) is a collection of networks, objects and devices connected via the Internet. It interacts with the internal and external environment. The IoT reacts accordingly, sensing the impact on the environment. It provides the environment with advanced technology and improves the quality of human life. IoT allows devices to communicate with each other physically or virtually. You can create an intelligent environment using IoT and connect at any time with any device. IoT is used to collect, analyze and process data from various drives and sensors, which are then transmitted wirelessly via smartphones or computers [1][2].

IoT is a set of several technologies such as embedded systems, widespread computing, drives, environmental research, sensors, Internet and communication technologies, etc.[3]

IoT is a combination of hardware and software. The main purpose of IoT is to connect the device and establish a continuous connection anywhere on the network. IoT has evolved from machine-to-machine connectivity (M2M). When M2M is connected, the devices connect to the cloud and manage the collected data [4].

Currently, the applications used in IoT are developing rapidly and play an important role in raising living standards in each of the IoT applications, including household appliances, smart energy, environment, industry, etc. and create a favorable environment [5]. IoT delivery services are used in transportation, logistics, automation and remote monitoring.

Smart cities applications can be recommended as the most common application of IoT [6][7]. It is used in smart cities to monitor the material condition of buildings and bridges. He also observes how there is some kind of vibration in the buildings. Lighting-provides smart and weather-adaptable light in street light systems. Transportation consists of smart roads and highways with warning messages and anomalies for any unforeseen events. It is used to ensure the safety of the population by identifying and preventing emergencies.

Security systems in "smart homes" of cities consist of fire extinguishing services, emergency notification, digital video surveillance and research works [8-10] have an extensive overview. In emergency situations such as earthquakes, fires, obtaining rational solutions for rescue and search work at the accident site allows to save human life and minimize the threat. In addition, such robots help identify people in an emergency situation using algorithms based on machine learning algorithms [11].

Arduino is a small single-chip computer board that can be used for applications and robot assistants based on IoT technologies, as well as for various creative hardware projects. It consists of an electronic unit and software. The electronic unit is a microcontroller and a printed circuit board with the elements necessary for operation. The second part is software development, including a simple development environment and the C/C++ programming language.

The hardware consists of a simple microcontroller board and a chipset. Programming is done through a Java-based IDE. Finally, Arduino is an excellent open source hardware platform for experimenting with the world of the Internet of Things. A small Arduino board can be used to create useful and interactive Internet projects. IoT automates human labor and reduces human resources.

**Related works.** In recent years, attention has been paid to the use of robots in search and rescue operations, due to their increased efficiency and safety in an emergency situation. Therefore, it is important to study modern technologies, applications, problems and future directions of using robots as assistants for search operations in emergency situations. Cardona Gustavo A. and Juan Calderon M. in their study research the movement of multi-robotic systems based on Swarm theory, modeling various extreme situations based on the consensus algorithm [12]. The authors note the possibility of using the device in search and rescue work.

Various robots are used in search operations, including ground-based, unmanned aerial vehicles and underwater robots. The paper presented by Queralta J. P and other authors provides an overview of multi-robotic systems supporting SAR operations, taking into account system-level ideas, as well as focusing on algorithmic perspectives of coordination and perception of several robots [13]. The various research topics relate to the various problems and limitations faced by different types of robots (surface, aerial, surface or underwater) and various search and rescue facilities (marine, urban, desert or other post-disaster situations). Chatziparaschis D. and other authors propose to combine aerial and ground robots [14]. The specified device can determine the shape of the human body based on the Darknet neural network.

Ground robots are usually designed as platforms, such as wheeled or tracked systems equipped with sensors for navigation and mapping.

Unmanned aerial vehicles have advantages in providing aerial reconnaissance, real-time situational monitoring and access to hard-to-reach regions. Chen Junjie and other authors are considering the possibility of providing an aerial robot with a holistic picture of complex urban disaster zones by combining ground-based radar (GPR) for unmanned aerial vehicles and other sensors such as the Global Navigation Satellite System (GNSS), inertial measurement Unit (IMU) and cameras [15].

Underwater robots are equipped with sonar and cameras for navigation and object detection, which is suitable for underwater search operations.

By their application, robots are an indispensable tool during natural disasters, search and rescue operations in cities or when searching for people in remote places. Novotny G. A. and other authors are designing a robot that will be used during a nuclear disaster [16]. The authors note that Mobile robots help to reduce risks and help rescue teams receive operational information, as well as help in garbage collection and search and rescue operations.

During a natural disaster: it telps to explore areas affected by earthquakes, hurricanes, floods and tsunamis, find survivors and deliver basic necessities. Firthous M. A. and Kumar R. study the directions of movement of robots during a natural disaster [17]. The proposed robots exchange information with other robots by determining a level of $CO_2$ in the regions.

In the Urban Search and Rescue Service (USAR): during the collapse of buildings or destruction of infrastructure, robots roam the ruins, detecting signs of life and providing rescuers an important information. The robot used in such conditions is presented by Sharmin S. and other authors [18]. The device is controlled remotely from the station and transmits thermal and video transmission of the accident site, as well as environmental sensor data through the control station to an associated web application.

SAR: Helps to find missing persons in remote or places difficult relief, perform search operations and deliver supplies to people in difficult situations.

Structurally, robotic assistants can be used by combining several sensors: LIDAR, thermal imaging and gas detectors and other sensors. This improves the reception capabilities of the device and allows to receive accurate emergency information and identify objects. Based on an autonomous navigation structure, the works allow to autonomously perform tasks such as localization, mapping and road planning, adapt to dynamic conditions and avoid obstacles. Human-robot interaction focused robots consist of user interface, gesture recognition and natural language processing systems. If the structure is focused on coordinating the actions of several robots, If the structure is focused on coordinating the actions of several robots, they can perform joint strategies such as group intelligence, task allocation and management algorithms and effectively cover large areas.

It is necessary to take into account the conditions that prevent an operation of assistant robots. For example, uneven terrain, climbing stairs or overcoming obstacles can be difficult, especially in crowded or enclosed areas. In addition, bandwidth limitations, signal interference and loss of communication can make it difficult to transfer real-time data between robots and control centers, interfere with coordination work. Power limitations and battery life limitations limit the endurance and operating range of robots, especially in long-term or remote missions.

The advantages of robot assistants are listed below:

– the use of miniature sensors, lightweight materials and reliable communication systems;

– artificial intelligence and machine learning models using: autonomous decision-making using artificial intelligence algorithms for object recognition, anomaly detection and decision-making. Seidalieva, U. in the work presented by other authors, they explore the prevention of emergency situations using video and image processing based on deep learning models [19][20]. Utebayeva, D. and other authors detect these situations using sound [21][22]. Momunkulov, Z. and other authors have created a deep learning model for detecting emergencies using the sounds of screams, breaking windows, explosions, weapons etc. [23]. The use of such deep learning models on robotic assistants increase the efficiency of search and rescue operations;

– development of common interfaces, protocols and standards simplifies interaction between different robotic platforms and improves compatibility between collaborative teams;

– issues related to privacy, data security and the ethical use of autonomous systems is crucial to ensure public trust and acceptance of robotic assistants in emergency response situations.

**Solutions. 3D model.** 3D modeling was performed to effectively position the external shape and components of the robotic assistant. It allows to design the physical structure, components and overall layout of the robot. The TinkerCAD application was used to design 3D model (see Fig.1 and Fig.2).

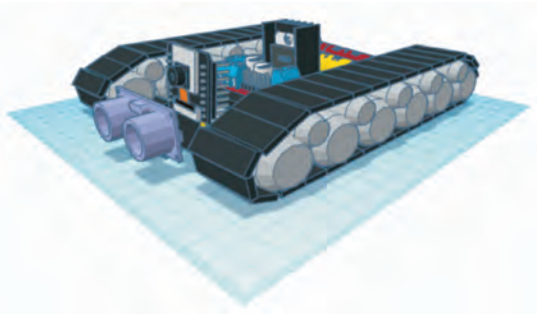

***Figure 1 –*** 3D model of robotic assistant

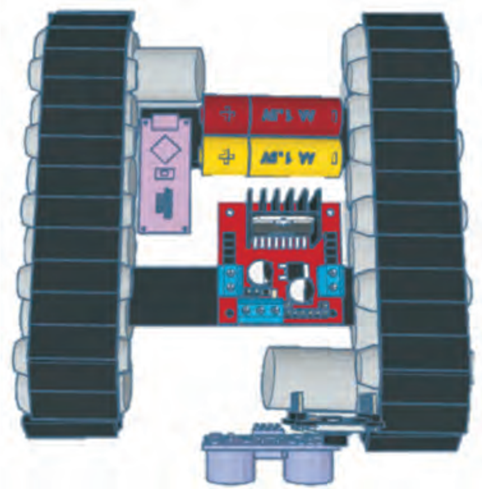

***Figure 2 –*** Design of device components on the platform

**Sensors.** An ESP32-COM camera with Wi-Fi and Bluetooth functions, an HC-SR04 ultrasonic sensor, infrared sensors and much more were used to collect environmental data, detect obstacles and detect objects. LED lights and a sound speaker were also used to attract people's attention. Simultaneous implementation of environmental mapping and positioning algorithms was performed using methods such as localization and mapping (SLAM).

**Communication module.** A wireless communication module (such as WiFi or Cellular) has been integrated to communicate with IoT devices, control centers or other robots.

**Power system.,** A reliable power system was installed using lithium polimer batteries with a nominal value of 7 V and power control schemes to provide enough power for the robot to operate in normal mode.

**Control.** The microcontroller was used to control robot movement, process sensor data and communicate with IoT devices. A web page has been prepared that allows to remotely monitor and control the robot, broadcast live video streaming and receive alerts (see Fig.3). The L298N integrated motor drive (IC) circuit was used to control the motors. For easy passing through difficult terrain and ithe rubble of destroyed buildings, the chassis was chosen in the form of a «caterpillar».

**IoT connection.** IoT protocols such as MQTT, CoAP etc. have been used for communication and data exchange between the robot and IoT devices or cloud platforms.

**Software.** It was noted above that a web page is used to control the robot. Sublime Text and an Internet browser were used to create the web interface (see Fig.3).

***Figure 3 –*** Designed robot control web interface

Libraries were used such as dl_lib_matrix 3d.h for camera operation; esp32-hal-led.h - for controlling servomotors; esp_http_server.h - for http server operation; esp_timer.h - for working with software timers; esp_camera.h and img_convertors.to work with the camera; Arduino.h - to connect the main Arduino library file to use standard functions.

**Algorithms and control systems.** The Arduino Nano microcontroller and Arduino IDE programming environment were used to control since the robotic assistant performing search and rescue operations was developed based on IoT technologies. The following is the assignment of the directions of movement (see Fig.4) and ultrasonic sensor settings (see Fig.5) in the Arduino IDE programming environment. A standard library NewPing was used for the operation of the ultrasonic sensor.

```
void f(){
  digitalWrite(m1, 1);
  digitalWrite(m2, 0);
  digitalWrite(m3, 0);
  digitalWrite(m4, 1);
}
void b(){
  digitalWrite(m1, 0);
  digitalWrite(m2, 1);
  digitalWrite(m3, 1);
  digitalWrite(m4, 0);
}
void r(){
  digitalWrite(m1, 1);
  digitalWrite(m2, 0);
  digitalWrite(m3, 1);
  digitalWrite(m4, 0);
}
```

***Figure 4 –*** Moving directions

```
else{
delay(200);
cm = sonar.ping_cm();
Serial.print(cm);
if(cm <= 30){
  s();
  delay(1000);
  b();
  delay(500);
  s();
  delay(500);
  if(random(2) == 1){
    l();
    delay(500);
    s();
    delay(500);
  }
  if(random(2) == 2){
    r();
    delay(500);
    s();
```

***Figure 5 –*** Setup of ultrasound sensor's parametres

If the distance is less than or equal to 30 centimeters, it performs several movements, including randomly choosing between stopping, rewinding, stopping again, and turning left or right before stopping again. If the distance exceeds 30 centimeters, it begins to move forward.

After initializing the code written in the Arduino IDE, we get the opportunity to control the robot in two modes: automatic and manual. After initialization, the code that manages the project goes into a repeating cycle and will run until the power supply on the microcontroller is exhausted. There are several command sequences that are important for manual control of the robot: these are commands for controlling the robot's forward and backward movement and commands for vertical and horizontal rotation. These commands are transmitted to the robot via a web page. The following commands are available in manual control mode:

- Connecting the camera;
- Turning off the camera;
- Moving the robot forward;
- Moving the robot backwards;
- Movement of the robot to the right;
- Movement of the robot to the left.

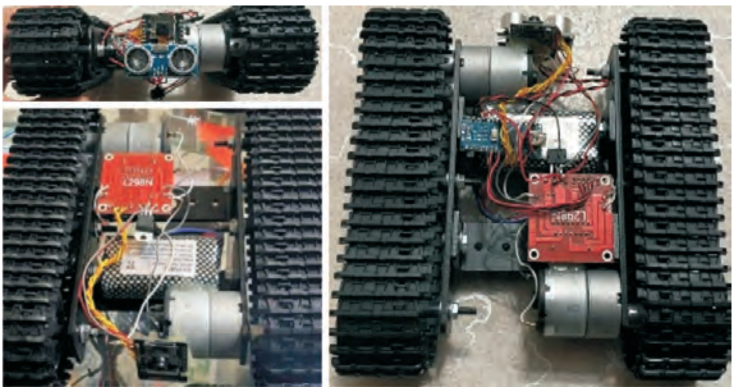


***Figure 6 –*** IoT based robot assistant for SAR operations

In addition, the robot also works in automatic mode, as mentioned above. That is, the robot is able to independently bypass objects and automatically determine the location of affected people.

A robotic assistant based on IoT technologies is shown in the figure above (see Fig.6).

**Conclusion and future work.** A hardware and a software components, including sensors, communication systems and data analysis solutions were considered to design a robotic assistant for search and rescue operations. The selection and implementation of these components plays an important role in the overall functionality and performance of the device.The development of a robot for search and rescue operations is a promising perspective solutions the case of emergency, natural disasters. This will reduce the risks to human life, response time and improve the efficiency of work in emergency situations.

In the future, the integration of machine learning models will be considered to identify victims on the base of audio and video data processing and make appropriate decisions.

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