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I. Nevliudov[1], S. Maksymova[1], O. Klymenko[2], M. Bilousov[1]

[1] Kharkiv National University of Radioelectronics, Kharkiv, Ukraine
[2] «Kapelou» LLC, Kyiv, Ukraine

DEVELOPMENT OF A MOBILE ROBOT PROTOTYPE WITH AN INTERACTIVE CONTROL SYSTEM

Abstract. One of the most urgent tasks of robotics is to perform work in conditions where a person cannot work, in extreme conditions. At the same time, the goal is to find a person at a distance, often a considerable distance, in safe conditions. From this follows the need to create robots that will be able to work by themselves either in autonomous mode or in remote control mode. At the same time, the task of detecting sources of combustion, which can be solved by a mobile robot equipped with specific sensors, is extremely urgent. Therefore, the task of developing an interactive control system for such a robot becomes urgent. The subject of this study is a mobile robot control program. The **purpose** of this article is to improve the efficiency of the fire safety system through the development of a mobile robot with appropriate sensors, as well as an interactive control system. To achieve the goal, it is necessary to solve the following **tasks**: analyze the methods of creating prototypes of mobile robots, develop a structural diagram of a mobile robot, choose components, choose the necessary sensors based on the goals of ensuring fire safety, develop an automated control system based on a modern single-board computer and intuitively develop clear operator interface. **Conclusions**: as a result of research, a structural diagram of a mobile robot was developed, its components were selected, it was assembled, equipped with sensors, and software was created that allows you to control it interactively. The developed prototype of a mobile robot will reduce the risk of fires and the need for human intervention, ensuring an operational response to danger. In addition, a mobile robot with the ability to independently navigate and recognize danger will ensure the optimization of work processes at various enterprises, or to check dangerous areas, improve the safety of workers or people around and reduce material costs. The result of the work is a functioning robot prototype with an implemented interactive control system

Keywords: mobile robot, ignition source, control system, fire sensor.

Introduction

In modern production, considerable attention is paid to ensuring human safety and reducing the risks of emergencies, including reducing the risk of fire due to various causes. In order to prevent the spread of fire, explosions in general, as well as explosions of equipment, damage to workers, and minimize costs, it is necessary to extinguish a fire as quickly as possible, or even better, to prevent it. For this purpose, it is advisable to use mobile robots equipped with temperature and fire detection sensors. Such robots should constantly monitor industrial premises and transmit information to the operator in real time.

The aim of this work is to improve the efficiency of the fire safety system by developing a mobile robot with appropriate sensors and an interactive control system.

A prototype of such a mobile robot will be developed, as well as an interactive control system for the mobile robot based on the Arduino board and the use of sensors that will enable the mobile robot to perform its tasks. The idea is to create a robot that can move independently and recognize dangerous situations, such as the onset of a fire and rising temperatures.

The developed prototype of a mobile robot will reduce the risk of fires and the need for human intervention by providing a rapid response to danger. In addition, a mobile robot with the ability to independently navigate and recognize hazards will optimize workflows at various enterprises or to inspect hazardous areas, improve the safety of employees or people around them, and reduce material costs.

The result of the work will be a prototype of a mobile robot with interactive control. It is a functional device capable of moving in the environment and interacting with the user. The mobile robot will be able to receive commands from the user, as well as respond to them, perform tasks and provide useful information. An important aspect is a user-friendly interface that will allow easy and intuitive interaction with the robot. In addition, the prototype will have additional functions related to monitoring the temperature in an industrial room and detecting open flames in it.

Analysis of recent studies and publications. There is a growing trend of emergencies in Ukraine and the world [1].

The main areas of fire safety are the elimination of fire conditions and minimization of its consequences. Facilities must have fire safety systems aimed at preventing exposure of people and material assets to fire hazards, including their secondary manifestations [2].

Based on the requirement to ensure the safety of people as much as possible, a progressive idea was the use of mobile robots to detect abnormally high temperatures and sources of fire in production. Many authors offer their own experience in developing both such robots and remote, preferably interactive, control systems for them [3-7].

A whole galaxy of researchers [8-11] suggest using the Arduino board to create firefighting robots, as well as those that detect fires. That is why we chose the Arduino Mega 2560 board in our work.

Purpose of the work. Improving the efficiency of the fire safety system by developing a mobile robot with appropriate sensors and an interactive control system.

The result of the work will be a prototype of a mobile robot with interactive control. It is a functional device capable of moving in the environment and interacting with the user. The mobile robot will be able to receive commands from the user, as well as respond to them, perform tasks and provide useful information. An important aspect is a user-friendly interface that will allow easy and intuitive interaction with the robot. In addition, the prototype will have additional functions related to monitoring the temperature in an industrial room and detecting open flames in it.

1. Selection of mobile robot components

This article proposes the development of a mobile robot with interactive control that can be used in industrial, warehouse, or residential premises to monitor and obtain information about temperature or fire.

The central component of the system is the Arduino Mega 2560 R3, which provides sufficient computing power and the ability to control various aspects of the robot. It serves as the basis and "brain" of the project, allowing you to program the logic of the robot and process data from sensors or sensors.

An example of the board is shown in Fig. 1.

Fig. 1. Arduino Mega 2560 board

The Arduino Mega 2560 board is one of the key components selected for the development of a mobile robot with interactive control. An important advantage of the board is its functionality. It is equipped with a powerful Atmega2560 microcontroller, which provides enough computing resources to implement complex algorithms and control various devices. The board also has a large number of digital and analog I/Os, which allows you to connect various sensors, actuators, and other peripherals.

The Arduino Mega 2560 supports a variety of software libraries and the Arduino IDE, which simplifies the programming and development process. It is also compatible with a large number of extensions and modules, which allows you to expand the functionality and capabilities of the system. It also has a fairly low cost. This board is widely available on the market.

The next important component for a mobile robot is the platform on which all the elements are located. We chose a mobile 3-wheeled transparent robot platform for robotics. Its appearance is shown in Fig. 2.

The platform is equipped with two motors with a deceleration ratio of 48:1. These motors provide enough power and torque to move the robot. They operate at 3-6V and have low current consumption, which is an energy-efficient solution. Three wheels, of which two are drive and sliding motors, provide stability and maneuverability of the robot. This allows for efficient movement in different directions and turns.

Fig. 2. Single deck robotic platform

This platform also has a battery compartment, which simplifies the integration of the power supply system into the robot structure itself. This ensures convenient and compact battery placement, which is especially important for mobile robots.

The next element will be the MB-102 solderless breadboard with 400 points. One of the key advantages of the MB-102 breadboard is its convenient design. The breadboard is shown in Fig. 3.

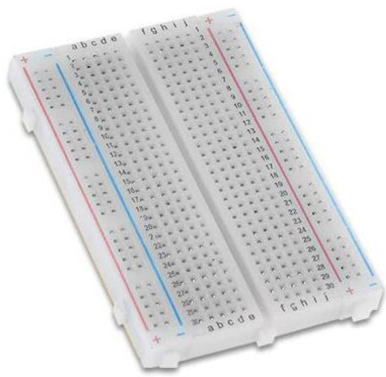

Fig. 3. MB-102 solderless circuit board

The board has 400 contact points, which provides enough space to connect various components, wires, and connections. This allows you to conveniently arrange circuit elements and make the necessary connections for testing and design. The breadboard also has high contact reliability and stability. Each contact point on the board provides a reliable electrical connection, which helps to avoid malfunction problems and ensures stable operation of the circuit.

The bridge driver plays an important role in the management and control of motors. The L293D bridged motor driver was selected to control two bridged motors. An example of a bridge driver is shown in Fig. 4.

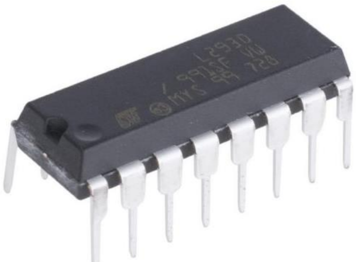

Fig. 4. L293D bridge motor driver for collector motors

The bridge driver ensures smooth and precise movement of the robot. The L293D provides stable and reliable motor control. It has built-in overload and back EMF protection to help prevent damage to components when changing direction or braking the motors. The bridge driver also allows you to control the direction of rotation of the motors and adjust their speed.

To connect all the components to the board, you also need a set of mother-to-mother and father-to-mother jumpers. An example of a set is shown in Fig. 5.

Fig. 5. Jumpers set

Next, we selected the necessary sensors. First, let's look at the ultrasonic sensor. This is a component that allows you to measure the distance to objects based on the principle of ultrasonic wave reflection. The HC-SR04 we have chosen is one of the most popular distance sensors and is widely used in various robotics projects. Its appearance is shown in Fig. 6.

Fig. 6. HC-SR04 sensor

The sensor consists of a transmitter and a receiver module. The transmitting module generates ultrasonic pulses that travel to the object and then are reflected back. The receiving module registers the reflected pulses and determines the time of sound wave travel. Based on the sound travel time and knowing the speed of air, the distance to the object can be calculated. The HC-SR04 can measure the distance to objects in the range of a few centimeters to several meters. This makes it versatile and applicable in a variety of scenarios. The sensor also has a simple connection and communication interface with a microcontroller. It works on the basis of the echolocation protocol, which simplifies programming and integration into projects. The selected instance is available at a low price and is readily available on the market. This makes it an attractive option for developing projects with a limited budget.

For communication and connection to wireless networks in the mobile robot project, the ESP8266 Wi-Fi module of the ESP-01 version was chosen (Fig. 7). This module provides a wireless Internet connection, which opens up a wide range of possibilities for remote control and data exchange.

Fig. 7. Wi-Fi module ESP8266 version ESP-01

The ESP8266 ESP-01 is a compact and cost-effective Wi-Fi module that offers sufficient performance and functionality to implement Wi-Fi communications. It is equipped with a microcontroller and a built-in antenna, which ensures its autonomous operation. The module allows remote control of the mobile robot using a smartphone, tablet, or computer. It can also be used to collect data from various sensors on the robot, such as distance, temperature, humidity, and other sensors. The collected data can be transferred to a remote server or cloud storage for further analysis and processing.

The KY-033 line sensor (Fig. 8) is a device specially designed to detect and follow lines on a surface. It is equipped with infrared sensors that respond to reflected light from the surface and allow you to determine the position of the line.

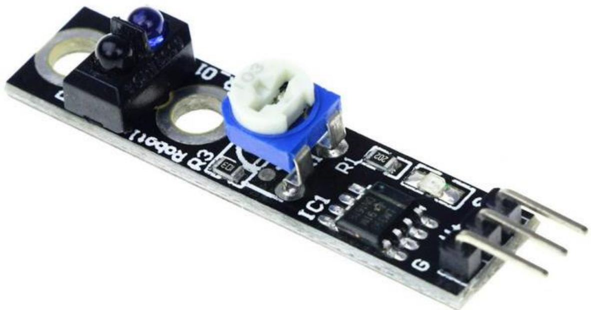

Fig. 8. KY-033 line sensor

The line sensor allows the robot to detect and follow a line on the floor or other surface. This can be useful, for example, for creating a linear route or an automatic navigation solution. It can be used to detect obstacles in the robot's path. If the line is interrupted or changed, the robot can react by changing its direction or taking appropriate action. If the robot is moving on a platform with edges or cliffs, the KY-033 line sensor can help it avoid falling or colliding. The robot can react to changes in surface color and adjust its movement to stay in the safe zone of the platform

The next sensor we chose was the KY-026 flame sensor (Fig. 9). It is a module designed to detect the presence of a flame, based on a photo-sensitive element that responds to changes in the intensity of light created by the flame.

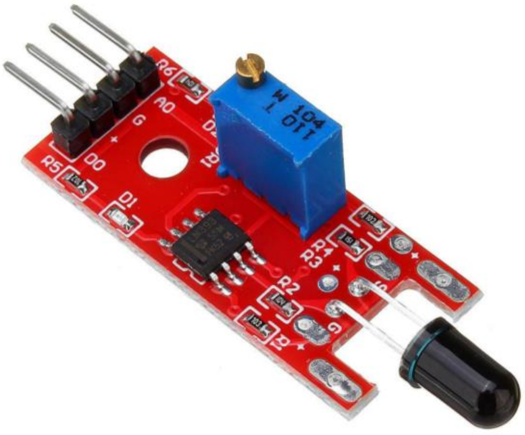

Fig. 9. Fire sensor

A sensor can be mounted on the robot for early detection of fire or other sources of flame in the environment. If flames are detected, the robot can activate appropriate safety systems or take action to prevent the spread of the fire. If the robot is used in areas where fires or dangerous situations are possible, the flame sensor can be integrated into a warning system.

When flames are detected, the robot can activate sirens, flash lights, or send an alarm to alert others to the presence of danger.

The last module to be installed on our mobile robot is an infrared thermometer (Fig. 10).

An infrared thermometer is designed to measure the temperature of objects using infrared radiation emitted by them.

It can work together with the KY-026 flame sensor to more accurately detect and measure heat or flame sources. In our case, the use of these two sensors allows us to measure the exact temperature of the flame source, complementing the information received from the flame sensor. This can be useful for determining flame intensity or monitoring temperature changes in the environment. The thermal module can also help detect hot spots or objects with elevated temperatures in the environment. This can be useful for detecting obstacles that could cause damage to the robot or other objects, as well as for determining temperature changes within certain areas.

Fig. 10. Infrared thermal module

2. Assembling a mobile robot

The structure of mobile robots depends on the tasks that the robot solves, but regardless of the tasks being solved, the main components of the mobile robot structure can be identified.

A block diagram is shown in Fig. 11.

Development of a circuit diagram. This circuit was created using the online tool Tinkercad, which allows you to design electronic circuits in a virtual environment. The main components of the circuit are two motors that are responsible for driving the robot's wheels.

The circuit also includes two ultrasonic sensors that are connected to a breadboard and then to an Arduino Mega 2560 R3 board.

The circuit is shown in Fig. 12.

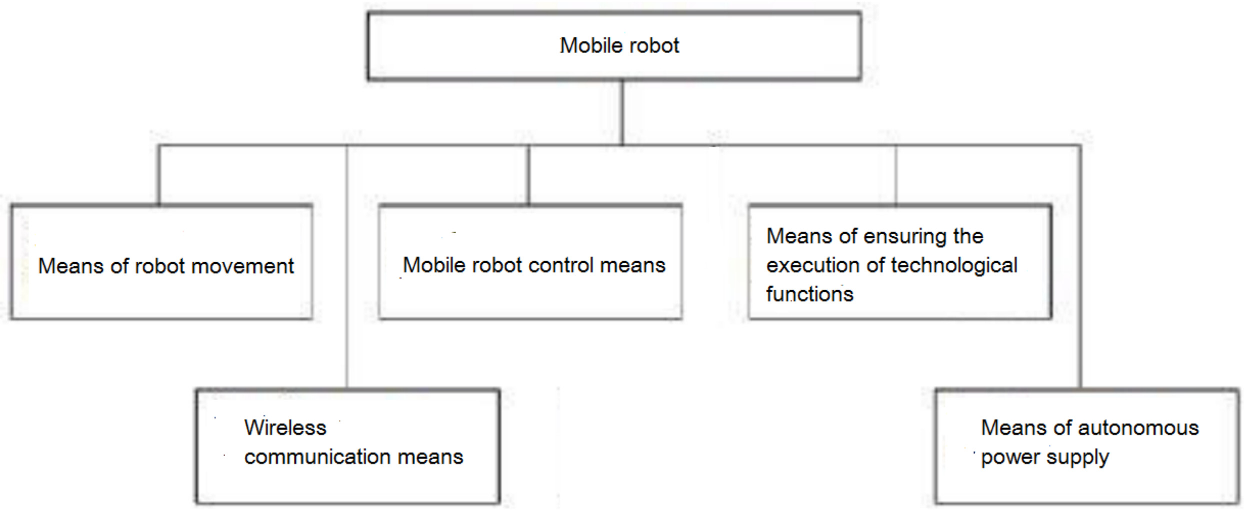

Fig. 11. Block diagram of a mobile robot

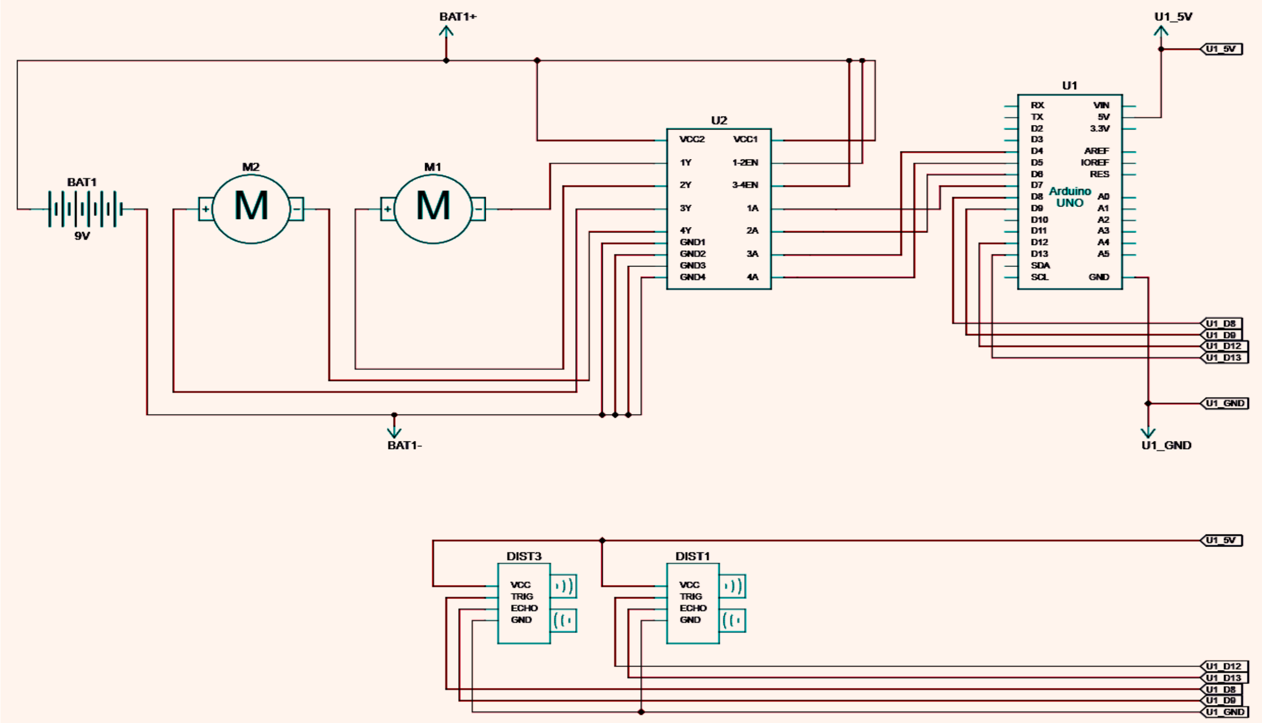

Fig. 12. Schematic diagram of the circuit

The connection to the prototype board is shown in Fig. 13 and 14.

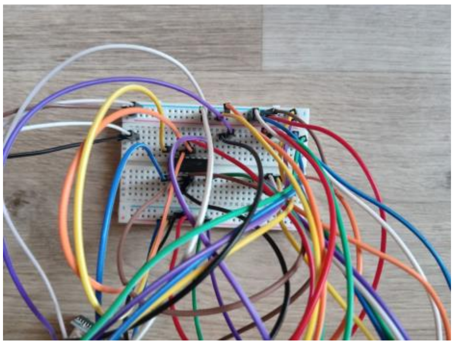

Fig. 13. Connecting to the prototype board

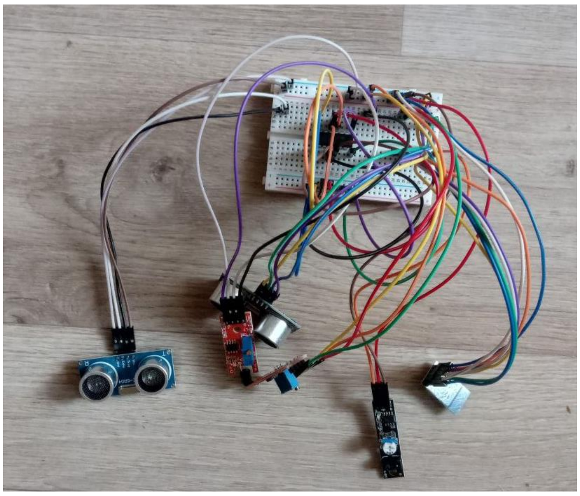

Fig. 14. Connection with sensors

Thanks to the Wi-Fi module ESP8266, we can theoretically realize the control of a mobile robot through a browser. The user, being in a local Wi-Fi network, opens a browser on his device. The mobile robot equipped with the ESP8266 module creates a web server on the module that listens for incoming HTTP requests. A web page with the robot's control interface is displayed in the user's browser. The user clicks buttons on the web page to control the robot. The browser sends a corresponding HTTP request to the robot's IP address and port. The ESP8266 module receives the request and interprets it as a command to control the robot's motors. The module transmits signals to the L293D bridge driver, which controls the robot's motors. The robot moves according to the commands received from the user via the browser. Thus, the user can control the mobile robot in real time (interactively) by clicking buttons on a web page in the browser, and the ESP8266 module transmits commands to the robot's motors through the bridge driver. The developed interface is shown in Figure 15.

Fig. 15. Example of a robot control interface

Conclusions

As a result of the above research, a prototype of a mobile robot has been developed that will reduce the risk of fires and the need for human intervention by providing a rapid response to danger.

In addition, this mobile robot has the ability to independently navigate and recognize hazards, which will optimize workflows at various enterprises or to inspect hazardous areas. Such a robot will improve the safety of employees or people around them and reduce material costs.

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Розробка прототипу мобільного робота з інтерактивною системою керування

І. Ш. Невлюдов, С.С. Максимова, О. М. Клименко, М. Ю. Білоусов

Анотація. Однією з найактуальніших завдань робототехніки є виконання робіт в умовах, де не може працювати людина, в екстремальних умовах. При цьому мається на меті знаходження людини на відстані, часто на значній, в безпечних умовах. З цього випливає необхідність створення роботів, які будуть здатні самі працювати або в автономному режимі або в режимі віддаленого керування. В той же час надзвичайно гостро стоїть завдання виявлення місць займання, яке може вирішити мобільний робот, оснащений специфічними датчиками. Отже, актуальною стає задача розробки інтерактивної системи керування для такого робота. **Предметом** даного дослідження є програма керування мобільним роботом. **Метою** даної статті є підвищення ефективності системи забезпечення пожежної безпеки за рахунок розробки мобільного робота із відповідними датчиками, а також інтерактивної системи керування. Для досягнення поставленої мети необхідно вирішити такі **завдання**: проаналізувати способи створення прототипів мобільних роботів, розробити структурну схему мобільного робота, обрати комплектуючі, обрати необхідні датчики, виходячи із цілей забезпечення пожежної безпеки, розробити автоматизовану систему керування на базі сучасного одноплатного комп'ютера і розробити інтуїтивно зрозумілий інтерфейс оператора. **Висновки**: в результаті досліджень було розроблено структурну схему мобільного робота, обрано його комплектуючі, зібрано його, обладнано датчиками та створено програмне забезпечення, яке дозволяє інтерактивно керувати ним. Розроблений прототип мобільного робота дозволить знизити ризик виникнення пожеж та необхідність людського втручання, забезпечивши оперативну реакцію на небезпеку. Крім того, мобільний робот зі здатністю самостійно навігувати та розпізнавати небезпеку забезпечить оптимізацію робочих процесів на різних підприємствах, або для перевірки небезпечних ділянок, покращить безпеку працівників або людей навколо та зменшить матеріальні трати. Результатом роботи є функціонуючий прототип робота з реалізованою інтерактивною системою керування.

Ключові слова: мобільний робот, місце займання, система керування, датчик вогню.