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Chenjian Dong [1], Jianjun Wang [2], S.P. Robotko[3], O.M. Susak[4], A.M. Topalov[3], V.V. Kolomiets[5]

[1]School of Automobile and Transportation, Yancheng Polytechnic College, Yancheng, China
[2]Yunzhou (Yancheng) Innovation Technology Co., Ltd., China
[3]Admiral Makarov National University of Shipbuilding, Ukraine
[4]Design Bureau IMT LLC, Ukraine
[5] Researcher of State Scientific Research Institute of Armament and Military Equipment Testing and Certification, Ukraine

FEATURES OF HUMAN-MACHINE INTERACTION IN THE SYSTEM OF WIRELESS CONTROL OF A MOBILE ROBOT

This paper considers the design features of human-machine interaction in the system of wireless control of a mobile robot. The requirements for user interfaces of computer systems are determined, and the stages and processes of creating a mobile robot control system and an operator's human-machine interface are analyzed. In the process of creating a control system, the choice of electronic components for creating a prototype of a mobile robot is substantiated, and a method for organizing a remote-control system based on Bluetooth technology is chosen. The connection scheme of the system components was developed, as well as the power supply unit of the mobile robot control system was selected. Arduino Nano with the appropriate hardware and software acts as the main microprocessor control device. The Java language and an integrated development environment were chosen for the development of the human-machine interface Android Studio. The developed user interface is a mobile application for controlling a mobile robot with the ability to program certain movement commands.

Keywords: *mobile robot, human-machine interaction, application, wireless communication.*

Ченьцзянь Донг, С.П. Роботько, Цзяньцзюнь Ванг, О.М. Сусак, А.М. Топалов, В.В. Коломієць

ОСОБЛИВОСТІ ЛЮДИНО-МАШИННОЇ ВЗАЄМОДІЇ В СИСТЕМІ БЕЗПРОВІДНОГО УПРАВЛІННЯ МОБІЛЬНИМ РОБОТОМ

В даній роботі розглянуто особливості проектування людино-машинної взаємодії в системі безпровідного управління мобільним роботом. Визначено вимоги до інтерфейсів користувачів комп'ютерних систем та проаналізовано етапи і процеси створення системи керування мобільним роботом та людино-машинного інтерфейсу оператора. В процесі створення системи керування обґрунтовано вибір електронних компонентів для створення прототипу мобільного робота та обрано метод для організації системи дистанційного керування на основі технології Bluetooth. Розроблена схема підключення компонентів системи, а також вибраний блок живлення системи керування мобільним роботом. В якості головного мікропроцесорного пристрою керування виступає Arduino Nano з відповідним апаратно-програмним забезпеченням. Для розробки людино-машинного інтерфейсу обрано мову java та інтегроване середовище розробки Android Studio. Розроблений користувацький інтерфейс представляє собою мобільний додаток керування мобільним роботом з можливістю програмування певних команд руху.

Ключові слова: *мобільний робот, людино-машинна взаємодія, додаток, безпровідний зв'язок.*

Introduction and statement of the problem. The modern development of robotics information technologies is characterized by the development of functionally complex computer systems, which include software and hardware complexes, protection systems, intelligent systems, decision support systems and a number of others [1-2], which make it possible to implement robot management systems with a given level of reliability, quality and efficiency. Remote control systems in combination with human-machine interaction play an important role in reducing the risks that arise during human work. Their use in robotics makes it possible to reduce the degree of physical presence of a person when performing work in dangerous conditions. They allow you to get safe access to hard-to-reach or dangerous areas, to carry out operative intervention of mobile robots in production processes with a high level of danger or to optimize working conditions. The special benefit of using such robots during explosive works (search, transportation, disposal or destruction of explosive objects and ammunition).

A large number of closely interconnected heterogeneous components of computer systems of robotics, the use of flexible and distributed software architectures affects human-machine interaction and requires the development and use of high-quality both software and hardware and user interaction tools [1-5]. Based on this, when designing computer control systems for a mobile robot, it is necessary to integrate

the process of building and evaluating the quality of human-machine interaction at all stages of the life cycle.

Analysis of the research and publications. Alan Kay made an invaluable contribution to the development of the graphical interface. He proposed the Dynabook concept, which defined the conceptual framework for the notebook, tablet computer, and e-book, and is the architecture of the modern windowed graphical interface. At the beginning of 1972, it embodied all the elements of the graphical user interface that we have today: the desktop, folders, windows. Moreover, a number of scientific and practical publications by both Ukrainian and foreign scientists are devoted to the process of ensuring and evaluating the quality of human-machine interaction. In particular, important results in the field of designing and ensuring the quality of human-machine interaction were obtained by such scientists as Lavrishcheva K.M., Kharchenko V.P., Guchenko I.V., Matias E., Dix A. and a number of others. Among mobile robotics, the work with the Micro:bit Smart mobile robot [6] should be singled out, which is the simplest example of a wheeled robot that has three wheels, two of which are leading, and they are also controlled because they are independent. from one, and the third wheel is the supporting wheel. The platform is based on the micro:bit controller, an ARM microcontroller developed by the BBC. Half the size of a credit card, it features Bluetooth, an accelerometer, a compass, three buttons, and a 5x5 LED matrix. The robot is controlled by human-machine interaction from a mobile application by means of wireless control of the power supplied to the collector motor-reducers. Another paper [7] presents a version of a tracked robot with control through a mobile application. The Doit T200 metal tracked transport platform of the factory design was chosen as the basis for the implementation of the experimental model of the robot. The features of this solution are that the body of this model is made of aluminum alloy, which makes it light and strong, as well as the presence of ready-made crawler motors with pressure rollers and light plastic tracks. The main focus is on the architecture of the control system and remote data transmission based on Internet of Things technologies using Arduino Uno and WeMos D1 R2 mini, the Blynk cloud service, and the human-machine interaction of the Android application.

From the review of the literature, it is clear that the development and improvement of modern systems of wireless control of a mobile robot using a human-machine interface is an urgent task.

Purpose work is the development and improvement of a remote control system for a mobile robot using modern approaches to ensure informative human-machine interaction of the operator with the mobile robot.

Presentation of the main material. Today, the analysis of communication options for remote control of a mobile robot is carried out using the Internet of Things (IoT) concept [3]. IoT, or the Internet of Things, is the concept of a computing network of physical objects (that is, actually things) that are equipped with certain technologies to interact with each other. Usually, the interaction of the mobile robot with the operator takes place with the help of an electronic computer, and various communication channels are used to organize the communication lines of the control object and the operator's monitor. For example, such as GSM, Bluetooth and Wi-Fi, which are part of the set of Internet of Things technologies. These technologies are very common, flexible in use, energy-efficient and economical, which simplifies the process of designing and developing a remote control system.

The user interface is the outer shell of any software system that allows the user to interact with the program. In fact, it is a set of means for processing and displaying information, maximally adapted for the convenience of the user [8-11]. In graphic systems, the user interface is implemented by multi-window mode, changes in the color, size, visibility of windows, their location, sorting of window elements, flexible customization of both the windows themselves and their individual elements, the availability of multi-user settings. In other words, the user interface is a type of interface in which, on the one hand, there is a person, and on the other, a machine (device, software).

The user interface provides support for decision-making in a specific subject area and determines the procedure for using the software and its documentation. In fact, the user interface combines all the elements and components of the software that can influence the user's interaction with the software. Such elements include: a set of tasks that the user solves with the help of software; used by the software of a particular shell (for example, "desktop" in the Windows operating system); software control elements; navigation between software blocks; visual (and not only) design of program windows and screen forms and other components (Fig. 1). The style of the user interface is a set of features, methods, methods of activity that characterize the individuality of the user interface, as well as a set of techniques for using software development tools.

The user interface design process is a complex, non-linear, non-deterministic and non-orthogonal process. The complexity of the user interface is determined by a number of uncertainties that significantly affect the development process. The non-linearity of user interface design consists in the absence of a fixed, orderly and straight-line algorithm from the beginning to the end of the design. The design process is uncertain because there is no equation that can produce the same result given the same initial conditions, and it is virtually impossible to produce an identical result. The user interface is non-orthogonal in the sense that any aspect of the design solution can influence other aspects, moreover, the result of this influence is not always positive and acceptable.

The process of designing modern software involves solving a number of tasks, in particular: reducing design costs, shortening design terms, improving the quality of the proposed solutions, providing easy-to-learn and use software, studying and implementing new technologies and tools, achieving better results compared to competitors. User satisfaction with a software product or its ease of use is largely determined by the user interface. In general, user satisfaction is a function of a small number of factors: user interface capabilities; response time; reliability; suitability for installation; information support; adaptability to accompaniment.

User interface capabilities should fully reflect the functionality of the application. The response time of the user interface should be minimal, so that the user does not have to wait longer than necessary for a given action. Reliability of the user interface is the ability to preserve over time within the established limits the values of all parameters that characterize the ability to perform the required functions in the specified modes and conditions of use. User interface maintenance is the process of improving, optimizing and eliminating defects after the software has been put into operation. Other factors include consistency, integration, and cost, which affect user satisfaction with the interface, and thus with the software product as a whole. All factors of user satisfaction and their relative importance should be considered during each stage of the user interface software life cycle.

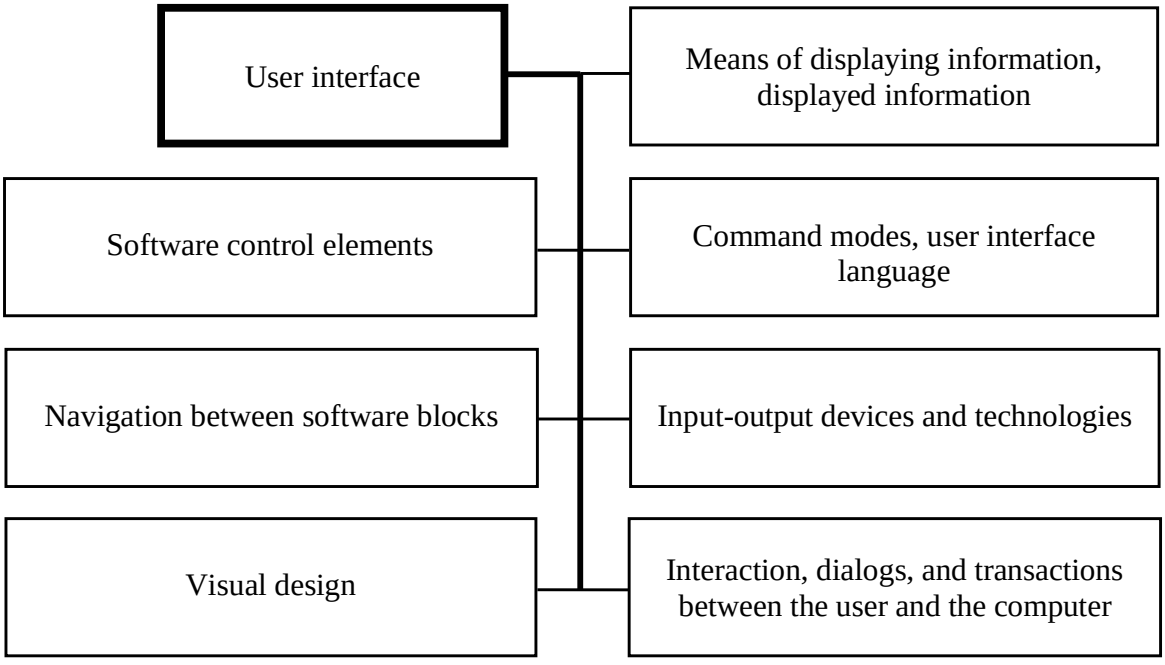


Fig. 1. **Components of the user interface**

The main task of human-machine interaction is to improve the interaction between a person and a computer, making computers more convenient (usable) and responsive to the needs of users. In particular, human-machine interaction deals with: the methodology and development of interface design (that is, based on the requirements and class of users, designing the best interface within the given framework, optimization for the necessary properties, such as the ability to learn and the efficiency of use); methods of implementing interfaces (for example, software tools, libraries and rational algorithms); methods for evaluating and comparing such interfaces; development of new interfaces and interaction technologies; the development of descriptive and predictive models, and the theory of interaction. The long-term task of

human-machine interaction is to develop a system that will lower the barrier between the human cognitive model of what they want to achieve and the computer's understanding of the tasks set before it.

In this case, the control system of a mobile robot, to be controlled remotely from a mobile phone, is considered. The P2P method will be used to organize the management system, that is, management will be without an intermediate link. Thus, the system will consist of a controller that will work as a server on the mobile robot and a third-party mobile application that will transmit commands directly to the mobile robot. An Arduino Nano is used as a controller, which processes the input data for control and executes the programmed instructions.

After analyzing the sources dedicated to working with Arduino, we conclude that this single-chamber microcontroller needs a DC motor driver to control the drive motor that will drive the robot structure. It is important for the driver to be able to control direction and speed. Among all options, we choose TB6612, which, thanks to its high efficiency, will increase the autonomy time of the mobile robot. Bluetooth wireless communication technology based on the HC-06 module was chosen for communication between the mobile robot and the operator. Because this communication channel allows you to get the ability to transmit commands without additional costs for a more powerful controller for working with network communication channels. This HC-06 module was also chosen because it operates from a 5V supply like the controller and has a sufficient signal range. The schematic diagram of connecting the electronic components of the mobile robot is shown in fig. 2 showing the power battery with the corresponding MT3608 DC-DC module, Arduino Nano, HC-06 Bluetooth module, steering servo motor, TB6612 and DC motor. Servo motor is connected to digital pin 12, Bluetooth module is connected to digital pins 2 and 4, TB6612 is connected to digital pins 7, 8 and digital pin 3 with PWM support.

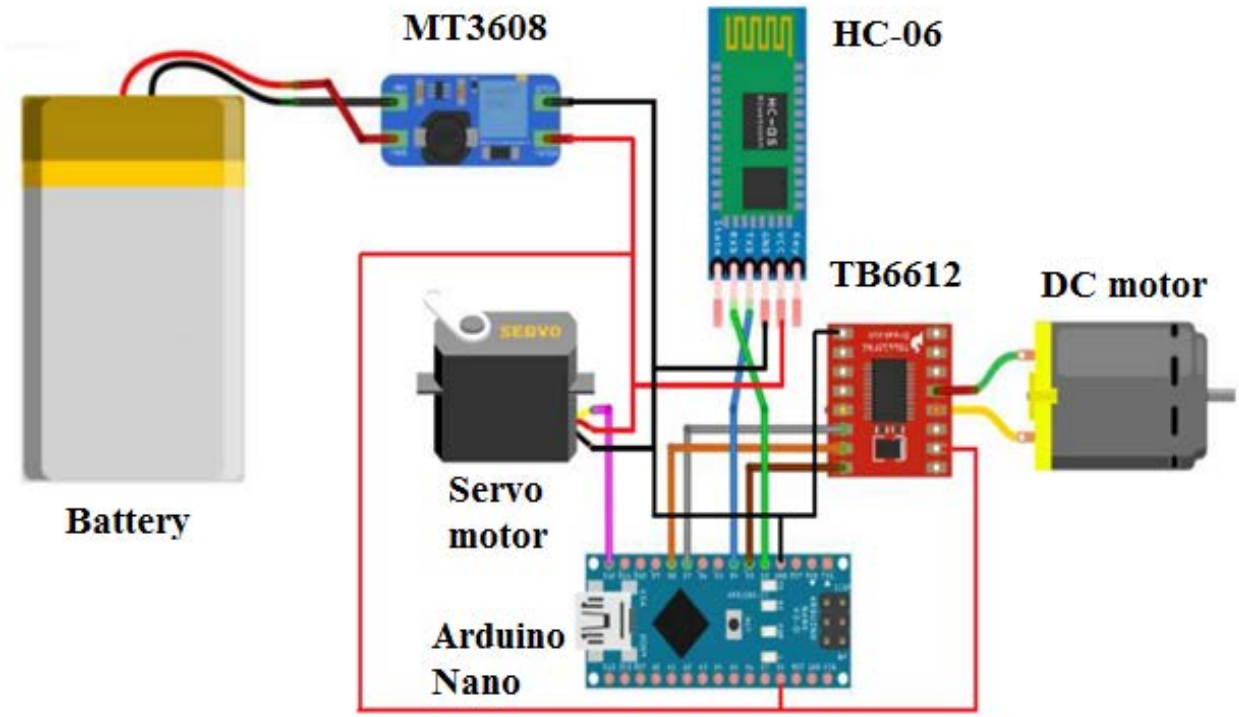
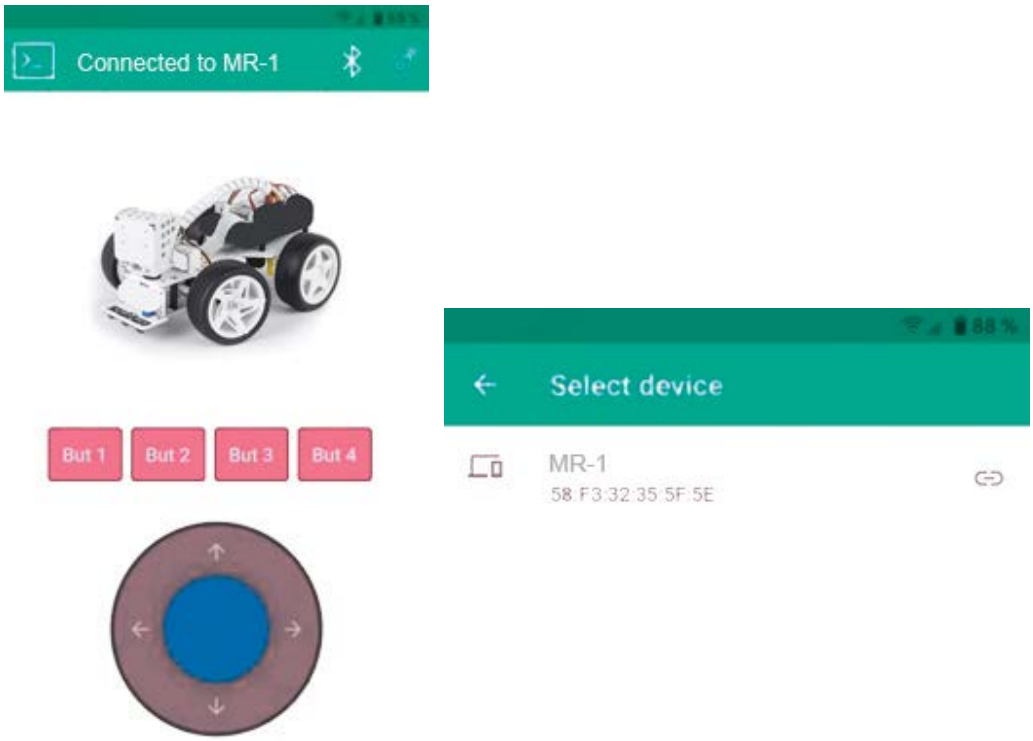


Fig. 2. **Mobile robot control system**

As a programming language for developing a human-machine interface for wireless control of a mobile robot, Android Studio is used as an official IDE for development on Android [12-14]. Android Studio offers a logically structured environment in which the program and user interface for a robot mobile application are developed in the Java programming language. The developed mobile application guarantees stable and prompt operation with smooth animation. UI design tools include all critical features such as scrolling, navigation, icons and fonts. Moreover, the graphical interface can be written in the form of an XML file.

The mobile application is installed using an installation file in apk format, or from the Google Play application store. To uninstall a mobile app, you need to open the settings on your mobile device and uninstall the mobile app by finding it in the submenu of installed apps. To launch a mobile application,

you need to find the application in the list of installed applications and click on its image. On fig. 3 a) shows the activated application in the vertical position of the screen. On the main window of the application, you can see the controls in the form of a joystick and four programmable buttons for sending commands to the mobile robot required by the user. At the top of the screen are the application controls, namely the button to open the terminal communication page, the button to select the device to connect to, and the button to open the settings page.



a) b)

Fig. 3. **Human-machine interface for controlling a mobile robot: a) main window with a connected device; b) Bluetooth device selection menu**

After launching the mobile application, the user needs to connect the mobile robot. To do this, you need to go to the Bluetooth device connection menu by clicking on the corresponding button at the top of the screen. If the user has not enabled Bluetooth on the device, an error message asking to enable Bluetooth will be displayed. In the figure, fig. 3 b) shows the menu for selecting a control device. After entering this menu, devices available for connection are searched and ready devices have black text.

To select a device for control, click on it (MR 1). The song of this application will return to the main window, and the connection will take place. After the user has connected the control device, he can immediately move the green joystick to control the movement of the robot.

Also, so that the user can send commands to the device, programmable buttons have been created that can be programmed once and send the desired commands again any number of times. To program a button for the desired command, you need to long press the desired button, and its menu will open (Fig. 4) . Saving the command and the desired name of the button happens automatically, to exit the button settings menu, press the back button. After opening the settings of the desired button, the user needs to enter the desired name for the button and the desired command, then to confirm the changes, the user needs to press the button called "Apply changes".

Conclusion. Human-machine interaction researchers develop new design methods, conduct experiments with new hardware devices, create prototypes of new software systems, study new paradigms for interaction, and develop interaction theories and models. Creating a high-quality human-computer interface, which can be called a point of contact between a person and a computer, is the ultimate goal of studying human-computer interaction.

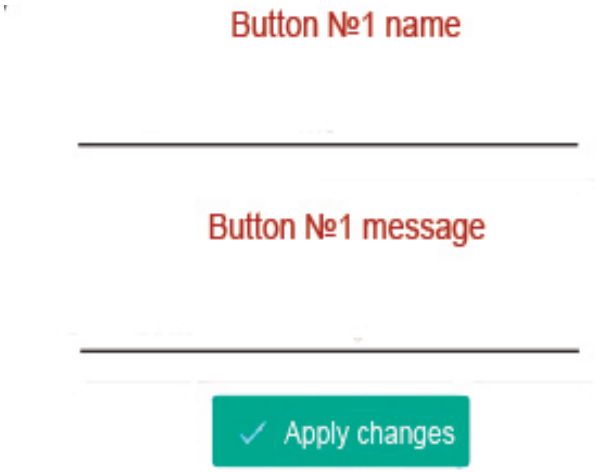


Fig. 4. **Programmable button settings**

The paper considers the development and improvement of a remote-control system for a mobile robot using modern approaches to ensure informative human-machine interaction of the operator with the mobile robot. Accordingly, the main principles of designing wireless mobile robot control systems and the problems of designing user interfaces were analyzed. Taking into account the requirements for convenience, safety and flexibility, constant technological development and increasing the automation of mobile robot systems, a human-machine interface was developed that provides the following functionality: editing the application in case of changing the robot model; application of technology as a wireless network Bluetooth ; constant monitoring of the movement of the mobile robot; possibility of programming buttons.

Potential users of the software product can be operators of mobile robots. This software product has both advantages and disadvantages over existing analogues and competitors presented on the domestic market. The mobile application together with the robot control system has a chance to develop and be filled with new functionality.

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Reviewer: Kozlov Oleksiy, Doctor of Technical Science, Professor of the Department of Intelligent Information Systems at Petro Mohyla Black Sea National University