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Preliminary communication

A Multi-purpose Mobile Robotic Platform with Measurement of Thermal Indicators of Objects and Remote Control

Oleksandr DOBRZHANSKYI, Andrii TKACHUK*, Anna HUMENIUK, Martin BOHDANOVSKYI, Vasyl BONDARCHUK, Ilona KRYZHANIVSKA

Abstract: Here, we present research results on developing a compact multifunctional mobile robotic platform based on tracks. Nowadays, choosing the optimal control system for such equipment remains relevant. We have proposed a system that allows measuring thermal indicators of objects or other environmental parameters in hazardous areas and can be controlled remotely via video channels and a specially developed free-programmable console. We also suggest using a steerable two-axis camera gimbal on a moving platform to implement enhanced VR/AR/FPV technology for efficient robot control. It provides a new quality of operator immersion in control compared to common land-based mobile platforms. With this in mind, we have presented the main points related to the set of components and algorithms of the control system, which is installed directly on the moving platform, and the control system that ensures the operation of the operator panel.

Keywords: algorithm; mobile platform; optical sensors; remote control; robotics; thermal indicators

1 INTRODUCTION

Mobile robotics is a fast-growing industry that allows us to advance into a future where autonomous systems and robots are integral to our daily lives [1-3]. Thanks to advances in artificial intelligence, sensors, mechanics, and other technologies, mobile robotics is becoming critical in industry, medicine, science, entertainment, and many other fields. Advances in mobile robotics are opening up new horizons for industry and society in general. They help improve productivity, efficiency, and convenience in various spheres of activity. However, with new opportunities come ethical and legal issues that require careful consideration. Mobile robotics is changing how we think about autonomy, efficiency, and interaction with technology. Our ability to use mobile robots is becoming more realistic every day. We are on the threshold of a new era in which mobile robots become reliable partners and employees. The mobile robotic platform for measuring the thermal indicators of objects is an automated system that can move and perform temperature and other thermal parameters measurements on different objects. This platform can be equipped with various thermal sensors, cameras, or other devices capable of reading thermal information from the surface of objects. This platform has a system of mechanical or robotic moving elements that allow it to move along the surface or around it. With the help of these movements, the platform can scan the thermal profile of the object and collect data for analysis. Using a mobile robotic platform for measuring thermal indicators of objects has several advantages. It allows you to measure a large area faster and more efficiently than stationary systems. In addition, the mobile platform can perform measurements at great heights or in hard-to-reach places where a person might have access problems. The applications of mobile robotic platforms for measuring objects' thermal indicators can be vast. For example, they can be used in the energy industry to measure heat loss in buildings or industrial facilities, as well as for military purposes in intelligence operations. Therefore, creating multi-purpose mobile robotic platforms is an urgent task today. Over the past ten years, problems of creating mobile robotic platforms for performing various specialized tasks have been widely discussed in Ukraine and the world. Articles [4-6] describe the state and prospects for developing robotic remote-controlled mobile platforms for military purposes. In [4, 5], turret positioning systems are described. These approaches need further investigation in the case of civilian mobile robotic platforms. A similar driving and cam-driving system as in [7] can be implemented for camera mounting and maintaining view direction. It is also worth considering the possibility of stabilizing the suspension where the camera is installed. Aviation inertial sensors, such as those in [8, 9], are suitable for large mobile platforms. Integral inertial sensors, such as those in [7] and [10, 11], are suitable for compact mobile platforms. Articles [12-15] describe the latest trends and spatial distribution of research activities in military robotics. Various technologies of military mobile robots and their applications in various fields, including surveillance, decontamination of explosive devices, and combat operations, have been studied. [16] describes a new mobile robot capable of scaling horizontal and vertical surfaces and uses micro-suction cups to provide adhesion for walking on different surfaces. But here, we are interested in the proposed models and algorithms that can capture real-time images, video, and audio to surveil a person or area. The robot is suitable for military surveillance and reconnaissance applications. In our research, we will improve such an approach and apply one to develop a robotic platform that can perform various measurement operations in hazardous areas. Papers [17, 18] propose a new strategy for human detection in complex underground (SubT) environments using a thermal imaging camera mounted on a drone based on an AlexNet Convolutional Neural Network (CNN). The effectiveness of the proposed scheme has been experimentally evaluated using several data sets collected from a FLIR thermal imaging camera during flights in underground mines, which fully demonstrates the effectiveness and advantages of the proposed module. However, the equipment described is controlled via a complex approach that needs to be simplified in the field application of a compact multifunctional mobile robotic platform. The latest research [19-21] deals with civilian mobile robots and concentrates on control systems that allow robots to maintain optimal trajectories in closed areas such as warehouses or enterprise areas. Robots with vision sensors and LiDARs for orientation are described in [19]. Mobile robots [20, 21] can perform various tasks outdoors. Still, their restrictions are as follows: robots are equipped with webcams, act in areas with Internet access, and require high-accuracy GPS and ideally organized roads. The emergency operator control of such robots has not been presented. We must provide reliable operator control facilities to work with robots in hazardous areas or field conditions. The most common and cheapest mobile ground robots for this aim are compact ground mobile robots based on tracks [22]. They are primarily suggested because they are highly effective in traversing soft and uneven terrains. Such ability is due to extensive ground contact surface [23]. In [22], a review of the newest models of mobile robots is presented on the market. It is important to note that all the models, despite their complexity, have not cam gimbals. Their vision sensors are fixed-mounted. Therefore, the operator needs to change position by moving the entire drone construction to change the view direction. It simplifies the control system but makes the operator's work extremely difficult, and the robot loses maneuverability and sensibility. As a result, all the information presented above indicates specific unresolved issues regarding the existing universal mobile platforms:

- most platforms need to be reduced in overall dimensions;
- platforms, where visual sensors are present, have ones that are rigidly fixed, which limits the operator's ability to inspect the environment while driving or stopping;
- almost all platforms, except large-sized military mobile platforms, are controlled via high-speed Internet data channels, which cannot be provided in the field (out-of-city) conditions;
- almost all platforms are developed on a closed software and hardware architecture, and those with an open hardware architecture demonstrate restrictions on free change in the software part;
- the presented ground platforms, which have a particularly important purpose, are primarily controlled not with the help of light consoles but with the help of rather complex systems that require computers, which partially complicates the work of the operator, although it provides certain additional features;
- among the available mobile platforms for specific purposes, there are no platforms that would be designed to simultaneously remotely recognize the visual situation and spatial distribution of the thermal field and measure the concentration of harmful gases; that is, there are no platforms that could be used in environments inaccessible to humans due to accidents and man-made disasters.

The goal is to develop a multi-purpose universal mobile robotic platform with the following distinguishing features:

- relatively lightweight and compact;
- have a camera gimbal that is capable of setting the direction of view in a wide range of spatial angles independently of the carrier mobile platform;
- have remote wireless communication channels that provide sufficient range and reliability of transmission of control signals from the console to the mobile platform, and vice versa, measured signals from the mobile platform to the operator console;
- have an open hardware and software architecture to make changes in case of clarification of the tasks performed by the mobile platform and to ensure its versatility;
- have a lightweight, multifunction console displaying measured digital and video information that is both compact and reprogrammable in a broad;
- the ability to measure and transmit analog signals to the remote control transmits video signals and signals from a thermal imager.

2 DESIGN AND DEVELOPMENT

2.1 Design of a Mobile Robotic Platform

A prototype of a multi-purpose mobile robotic platform (Fig. 1) has been developed for measuring the thermal indicators of environmental objects, for remote control for conducting reconnaissance operations, and, optionally, for monitoring the presence of harmful and explosive gases.

Figure 1 Mobile multi-purpose robotic platform for measuring thermal indicators of objects and remote control

The mobile robot is built based on a low-noise tracked chassis, which has increased cross-country ability. The material of the mobile robotic platform is high-strength aluminum alloy. An analog camera with infrared illumination is placed on the chassis, which allows video recording even at night. A thermal imager is installed next to the video camera. All optical sensors are placed on a specialized mobile turret with a rotation angle of 360 degrees. A mobile robot remote control panel is designed and developed, which includes a display and joysticks to control the robot's movement and a turret to rotate the optical sensors, respectively. VR/AR/FPV technologies are also used to make robot control more convenient. The main elements of the functional scheme can be conditionally divided into three groups: sensor, executive, matching, control elements, power elements, and communication elements. We present their list in tables (Tab. 1 and Tab. 2), where we also note the functional purpose of each element. Functional diagrams of remote control and mobile platform control systems corresponding to the list are represented by block diagrams (Fig. 2 and Fig. 3). The

following control modules are presented on the mobile platform:
- a central control module based on a Raspberry Pi microprocessor board;
- servo motor control module of the camera suspension based on PCA9685 microprocessor board;
- the control module for the main power engines of the platform based on the L298 microcircuit;
- control module for transmitting/receiving radio signals to/from the operator control panel based on the RFD900+ microprocessor board;
- a module for converting the AV signal from the camera to a 5.8 GHz frequency channel signal based on the TS5823S microprocessor board (or a similar FPV Video Transmitter);
- optionally, a module for measuring environmental pollution parameters (concentration of gases) based on an analog-to-digital and digital-to-analog conversion AD board with ADS1256 converter integrated circuits with a sensor array.

Table 1 A list of the main elements of the mobile platform

Group of elements	Element	Functional purpose
Executive elements	Motors (direct current) of the main movement	Driving right/left tracks of the mobile platform with the ability to adjust the speed of movement
	Camera suspension servomotors	Driving and positioning camera
Power elements	Larger capacity batteries	Power for the camera gimbal and main motion drives, the cameras themselves, the matching devices used, and the video signal transmitters
	Power supply voltage stabilizer for consumers of larger capacity batteries	Stabilizing the power supply voltage of the camera suspension drives and main motion drives, the cameras themselves, the applied matching devices, and video signal transmitters
	Batteries of smaller capacity (independent connection)	Power for the main transmitter/receiver for receiving/transmitting control signals
	Power supply voltage stabilizer for consumers of smaller capacity batteries	Stabilizing the power supply voltage of the main transmitter/receiver of the transmission of control signals
	Battery	Power for the processor board of the mobile platform central control
Control elements	Central processor board for managing the hardware part of the mobile platform	Issuance of control signals for main movement drives, control signals for camera suspension drives, communication with the control panel of the mobile platform operator
Elements of agreement	Low-power servo motor control driver	Controlling of servo drives of the camera suspension by signals from the central control processor board
	DC motor control driver	Controlling of main motion drives by signals from the central control processor board
	AD converter (option)	Receiving the signals from sensors (option) with analog output
Communication elements	Analog video transmitter #1	Transmitting the signal from the night vision video camera to the remote control display
	Analog video transmitter #2	Transmitting the signal from the video camera-thermal imager to the remote control display
	Transmitter/receiver of control signals	Information exchange between the control panel and the mobile platform
Sensory elements	Thermal imager video camera	Surveying to assess the distribution of heat in the surrounding space
	Day/night vision video camera	Shooting objects of the surrounding space in normal conditions and conditions of darkness
	Chemical concentration sensors (option)	Measurement of the concentration of extraneous chemicals in the air

There are control modules on the operator panel of the mobile platform:
- central control module based on Raspberry Pi;
- control module for transmitting/receiving radio signals to/from the operator control panel based on the RFD900+ microprocessor board;
- optionally, a module for measuring environmental pollution parameters based on an analog-to-digital and digital-to-analog conversion AD board with ADS1256 converter integrated microcircuits with potentiometer elements of biaxial XY joysticks KY-023;
- optional LED display module for displaying measured data about the state of the environment at the location of the mobile platform;

optionally, a 9-DOF (3-DOF, 6-DOF) sensor module to control the position of the suspension with cameras based on a board with LSM303DLHC and L3GD20 chips.

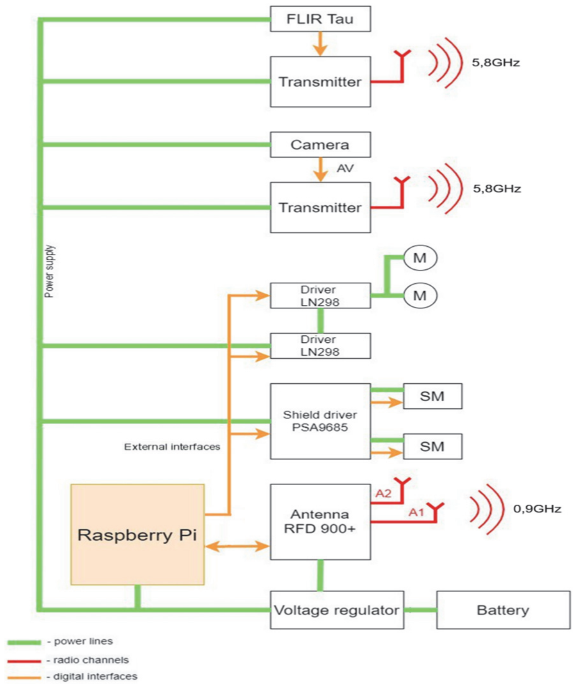

Figure 2 The structure of the system for directly controlling the hardware part of the mobile robotic platform

Table 2 A list of the main elements of the mobile platform remote control

Group of elements	Element	Functional purpose
Power elements	Battery (power bank)	Power for the processor board of the central control panel of the operator of the mobile platform
	Battery (power bank)	Power for the display of the operator panel
	Battery (power bank)	Power for the main transmitter/receiver for receiving/transmitting control signals
Control elements	Board of the central processing unit for controlling the hardware part of the remote control of the mobile platform	Issuance of control signals for transmitting to main motion drives, camera suspension drives, and communication with the mobile platform control board
Elements of agreement	AD converter (option)	Receiving signals from sensors (option) with analog output
Communication elements	Analog video receiver #1-2	Receiving signals from a night vision video camera on the remote control display, receiving a signal from a thermal imager video camera
	Display	Display of signals from the night vision video camera and the thermal imager video camera on the remote control display
	Analog video receiver (option)	Receiving a signal from a night vision video camera on a remote control display, receiving a signal from a thermal imager video camera
	VR/AR/FPV goggles (option)	Display of signals from the night vision video camera and the thermal imager video camera on remote control display in the mode of immersion (line-of-sight) of the operator in the space around the mobile platform
	Transmitter/receiver of control signals	Information exchange between the control panel and the mobile platform
Sensory elements	Discrete sensor buttons and switches	Fixing the settings and operating modes of the mobile platform
	Analog sensors-joysticks	Controlling the mobile platform camera suspension and controlling the main motion drives of the mobile platform
	Spatial position sensor (option)	Automatic synchronous controlling of the camera position of the mobile platform is coordinated with the position of the operator gaze in the VR/AR/FPV goggles

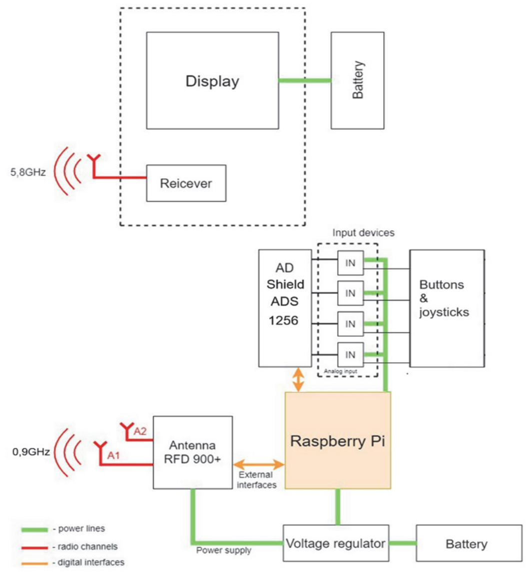

Figure 3 The structure of the remote control system of the operator of the mobile robotic platform

2.2 Mobile Platform Management Algorithm

The main algorithm will be developed for its implementation in the Raspberry Pi software environment. All other modules require either initialization during the execution of the main algorithm or preliminary configuration using other software tools. In executing the main algorithm, these same modules will require the following signal structures to be sent to them: control discrete signals, control commands, writing commands, reading commands, and information messages. The control algorithm must consider the presence of the interfaces: the interface of discrete output signals, the interface of discrete input signals, the interface of PWM output signals, the I2C interface, the SPI interface, and the RS-232 interface. That is, before setting up the functional modules of the mobile platform management system, it is necessary to initialize (set up) the interfaces, with the help of which, in turn, the setting of external modules (peripheral devices) will take place. To create a mobile platform control algorithm, we need the main algorithmic elements: software setting of I2C, SPI, RS-232 interfaces, discrete physical inputs and outputs, PWM outputs, and program execution by the central control module. The created main program design allows to perform the following functions:

- reading data through the specified interfaces,
- transmitting data through the specified interfaces,
- processing the read data,
- checking limit values,
- selecting the operating mode of the mobile platform devices,
- determining new values of control signals and normalizing these values,
- forming and transmitting control commands through the specified interfaces to the mobile platform devices.

The presence of a central control module for the remote control and the same separate module for the mobile platform necessitates the development of two separate control algorithms. When developing a mobile platform control algorithm, the sequence of launching platform modules is worth considering. It also considers the sequence of external power control switches' states and enables switches on the mobile platform operator console. The algorithm for controlling the platform and devices of the mobile platform operator remote control must control three switches:

- the switch for allowing data transmission to the radio transmitter (on the remote control),
- the switch for allowing the reading of data received by the radio receiver (on the platform),
- the switch for controlling the position of the camera suspension based on the signals of the position sensor on the VR/AR/FPV goggles.

The algorithm of operation of the mobile platform operator remote control

Stage 1 (Setup and initialization of remote control system):

1) Import of libraries and modules. Libraries and modules are necessary for implementing system functions, time

counting functions, input-output functions, mathematical calculations, and configuration of the sensor of the spatial position of the VR/AR/FPV goggles (for the optional subsystem - option - 1).

2) Downloading hardware configurations. This operation is performed for physical inputs/outputs, the external AD module, and the communication channel with the spatial position sensor, optionally.

3) Initialization of hardware. This action involves activating the physical inputs, serial port, software object of communication with the AD module, and, optionally, communication channel with the spatial position sensor.

4) Clearing the hardware serial port data buffer to prepare the physical port to load a new batch of data. It also prevents the system from reading "garbage" from the data buffer left over from previous messages.

5) Initialization of the data downloading software array. The array stores data-control signals from the mobile platform remote control (operator console). Preparation of a separate array allows you to keep all the read data in one consistent set in the future and easily edit the code if you need to add another control command.

6) Initialization of the data uploading software array. The array is designed to store data-measured signals from sensors of the state of the surrounding environment (option), which will be sent via the radio to the mobile platform operator console.

Stage 2 (Main cycle of remote control system):

1) Checking the presence of a signal from the switch of permission to transfer/read data to/from the radio module. If the switch is turned on, permission is given to start the main cycle. Otherwise, the primary cycle does not start.

2) One of the primary operations is to read the AD registers of the module into the software array of data downloading. In this way, signals for controlling the movement of the mobile platform and the camera suspension are received. The signals from the potentiometers are converted into digital form by the AD module, read by the central control module of the mobile platform operator remote control, and sent through the radio module of the remote control to the mobile platform. The peculiarity of working with the AD module is that you must wait for a response about the measured values from this module until it performs the analog-to-digital conversion.

3) An attempt to read from the serial port the data received by the radio module from the central control module of the mobile platform about the measured parameters of the environment's state at the mobile platform's location (if such an option is installed). If a read error occurs, the data will still arrive on one of the subsequent iterations of the loop. If no error occurs, it is possible to output data to the LCD of the mobile platform operator's remote control.

4) Checking the signal from the camera suspension control permission switch on the mobile platform based on the signals from the spatial position sensor on the VR/AR/FPV goggles (optionally). If the switch is turned on, the central control module of the operator panel will receive a signal from the spatial position sensor of the VR/AR/FPV goggles. Note that to control the position of the camera suspension, there is already a signal from the potentiometers of the mobile platform operator console. Still, it needs to be "replaced" or adjusted with the correspondingly obtained value of the angular position of the VR/AR/FPV goggles from the spatial position sensor. If so, data correction is performed for the corresponding element in the loaded array according to the spatial position sensor data.

5) Regardless of whether the camera position is regulated by signals from the spatial position sensor of the VR/AR/FPV goggles or only by signals from the potentiometers of the mobile platform operator console, it is necessary to perform at least elementary filtering of the measurement information. The easiest way to do this is with an algorithm based on averaging with a previous value in time. This algorithm is used in various automation systems for slow and fast signals. Averaging in its simplest form can be done by simply adding the current value of the measured parameter to the previously measured value and dividing the result by two. The final result of the calculation is taken as the result of the measurement and stored in the loaded array, and the next iteration of the loop will be used as the result of the previous measurement.

6) When the measurement data is generated, it is ready to be transmitted over the radio channel to the central control module of the moving platform. Thus, data is transferred from the boot array to the serial hardware port buffer and from there to the hardware port buffer of the RFD 900+ radio transmitter board.

7) A feature of the transmission of control signals over a radio channel is the transmission of the entire set of all available control signals in one packet. The packet enters the radio communication module buffer on the mobile platform central control module when the transmission occurs. It takes time to read them. If you do not withstand this time, then the data in the buffer of the radio module will be "erased" by new data received from the radio module of the operator remote of the mobile platform, even before the central control module of the mobile platform reads them. Including an additional timeout timer (a time interval for reading on the receiving side of data) allows you to give the receiving side time to read data from the buffer of its radio module.

After some waiting for the end of the timeout, the address pointer of the program commands moves to the beginning of the primary cycle.

Similar operations are provided in the mobile platform control algorithm, considering some features.

The algorithm of the mobile platform functioning

Stage 1 (Setup and initialization of the mobile platform system):

1) Import of libraries and modules. Libraries and modules are necessary for implementing system functions, time-counting functions, input-output functions, mathematical calculations, communication with the servo driver of the camera suspension motors, and sensors of the state of the surrounding environment (for the optional subsystem).

2) Downloading hardware configurations. This operation is carried out for the system of physical inputs/outputs, external AD module, external servo driver of the camera suspension motors, and communication channel with the sensors of the surrounding environment (optionally).

3) Initialization of hardware. This action involves bringing the physical inputs, serial port, the software object of communication with the AD module, the software object of communication with the servo driver, and the

communication channel with the sensors of the surrounding environment (optionally).

4) Cleaning the data buffer of the hardware serial port (preparing the physical port to load a new portion of data into it; this also prevents the system from reading "garbage" from the data buffer, which is left over from previous messages).

5) Initialization of the data loading software array (the array is designed to store data - signals received from sensors of the state of the surrounding environment (optionally) located on the mobile platform; preparation of a separate array is performed in the same way as for a similar array for the mobile platform operator console).

6) Initialization of the data downloading software array (the array is designed to store data-control signals from the mobile platform operator remote control, received via the radio channel from the mobile platform operator remote control).

Stage 2 (Main cycle of the mobile platform system):

1) Checking the presence of a signal from the read/transfer permission switch to/from the radio module. According to the same scheme as on the mobile platform operator console, permission is given to start the primary cycle if the switch is turned on. Otherwise, the main cycle does not start. This switch is expected to be turned on.

2) Reading the AD registers of the module into the software data loading array. In this way, signals are received from sensors of the state of the surrounding environment (option). Signals from the sensors are converted into digital form by the AD module, read by the central control module of the mobile platform, filtered, normalized, and sent through the radio module of the mobile platform to the central control module of the operator console.

The following few stages involve working with a serial port to which a radio module is attached to read a packet of mobile platform control signals. The peculiarity is that in case of receiving damaged information (lack of integrity, incomplete packet, noisy data, etc.), it is necessary to clear the clipboard to try to receive the next packet sent from the mobile platform operator's remote control.

3) An attempt to read from the serial port the data received by the radio module. Note that the command is executed temporarily while waiting for full data reading. For this purpose, the data transmission timeout and the number of retries (in case of a negative attempt) are set on the serial port. In case of completion of reading the buffer register of the radio module into the buffer register of the central module of the mobile platform control, a check for the presence of a reading error is performed. Count the number of failed reads and retry reading the data if an error is detected. When the limit of failed readings is reached, the rational action will be to clear the data buffer on the radio module completely. If no error is detected, it is possible to fill the boot array.

4) Filling the loading array with the data received by the radio module. It is a packet of mobile platform control signals. These include the control signals for the mobile platform drive motors and the position of the camera gimbal.

5) Using data about the sequence and speed of turning on the mobile platform motion engines, a signal should be fed to the engine driver module. The generated signal should be checked for being within the permitted range and adjusted. When the preparatory stage is completed, it is possible to transfer the physical outputs of the controller discrete and PWM control signals of the main motion motors' external drivers to the controller discrete's physical outputs.

Practice shows that, in addition to checking the signal output for the maximum range, you should also check the presence of the signal in the range of small values. The system can recognize random deviations as a helpful signal, which is undesirable. The following graph of insensitivity zones for the direction control signals of motors is proposed.

Stage 2 (side cycle - parallel to the main cycle):

The cycle is intended for separate synchronous control of the servomotors of the camera suspension. Due to the asynchrony of the arrival and reading of signals from the radio module, if there are commands to control the outboard servomotors after that, there will be a delay in sending commands to the servomotor driver and, as a result, instability of the control signals over time. Therefore, the reading and filling of the data loading array occur in the primary cycle, and the servo motor control commands are submitted in the side cycle. The stages of the side circle:

1) Description of the parallel flow for commands to control the servomotors of the camera gimbal. A complex object defines the parallel thread and the function to be called by the parallel thread.

2) The start of a separate thread execution is performed using special commands on the object describing the parallel thread.

3) Reading the current state of the camera position data from the loaded array. While in a parallel thread, commands access the main thread variables as if they were global. It simplifies the work by allowing data to come through the radio module from the mobile platform operator console. The read values are then converted into control signals for the external servo motor driver module by an appropriate function that considers the appropriate signal gain, offset, etc.

4) As in previous cases, check the maximum values and adjust the control signals.

5) When the signals about the camera's new position are ready to be loaded into the external driver module, it is possible to transfer them through the corresponding physical port configured in the main program (main thread). In practice, data loading to the external module driver does not happen instantly either, so the download command expects a confirmation of the download from the external module addressee.

At the end of the loading operation, there is a transition to the beginning of the cycle nested in the side parallel flow.

3 CONCLUSION

When solving the initial tasks, the following steps and solutions were performed, which can be generally described below. A new mobile multi-purpose robotic platform with measurement of thermal indicators of objects and remote control is considered. The platform is equipped with a day/night-vision camera, a device capable of reading thermal information from the surface of objects - a thermal imager, and a range of gas sensors that can be installed optionally. The robotic platform models of control modules and types of control/measured signals are determined. A description of the developed mobile robot remote control is given, which includes a display and joysticks for controlling the movement of the robot and a turret for spatial positioning of optical sensors. The functional schemes of remote control and mobile platform control systems are presented. Virtual Reality (VR) or Augmented Reality (AR) technology can also be used to facilitate robot control and create an immersive First-Person View (FPV) environment for the operator. The control algorithm must consider the presence of the following interfaces: discrete output signal interface, discrete input signal interface, PWM output signal interface, I2C interface, SPI interface, and RS-232 interface. The algorithm of the central control module functioning, installed on the mobile platform, has the section of outputting control of the physical orientation of the camera in space into a separate program flow. When developing the mobile platform control algorithm, the sequence of launching platform modules is considered, which also considers the sequence of states of external power control switches and enable switches on the mobile platform operator console. The stages of the operation algorithm of the operator panel of the mobile robotic platform are defined and described. More specifically, the research developed a universal, compact, lightweight mobile measuring system with the possibility of remote wireless control and data visualization. As a prototype and based on the developed principles and methods, a remote-controlled mobile platform was created for remote thermal and visual environmental monitoring. The prototype can be described according to the following parameters, which indicate the possibility of solving the assigned tasks:

- the problem of lightness and compactness is solved due to the use of high-strength aluminum alloy as the frame material of the mobile platform frame, the use of lightweight plastic parts that are printed on a 3D printer (using Flame-Retardant Filaments for fire resistance), as well as a control system based on lightweight miniature integrated modules;
- the problem of creating a movable video camera was solved by using a light two-axis bearing suspension, which is driven by two servo motors with metal reducers, based on servo drives such as EMAX ES08MA II 12G with a power of 12 V and 2 kg×sm torque;
- the problem of ensuring the wireless transmission of signals between the platform and the operator console is solved by choosing two separate specialized long-range digital transmitters and receivers: the first is a video signal transmitter based on module TS5823S with a power of 1 W and 5.8 GHz frequency channel that provides standard FPV signal format; and the second is a transmitter/receiver that organizes data exchange between the console and the mobile platform, based on a module RFD900+ with adaptive transmit power and 0.9 GHz frequency channel; both provide connection in the range from several hundred meters to 1 kilometer under the condition of the line of sight;
- the problem of open hardware structure is solved with the help of a system of universal components available on the market, with the help of which the system is assembled on a modular principle using universal interfaces such as I2C, SPI, UART;
- while the power components can be replaced according to the power of the mobile platform, we recommend a Raspberry Pi microcontroller with a system of universal ports and interfaces as a control board, as well as an ADS1256 DA converter shield circuit for it with the ability to measure analog signals; that is done for both central control modules of a mobile platform and operator panel
- the Raspberry Pi microcontroller also solves the problem of openness and flexibility of the software, as it uses editable scripts based on the Python language, which run under the control of the Linux operating system, and editing and configuring the script can be done at any time by connecting the peripherals to the Raspberry Pi;
- the possibilities of reliable signal measurement with the help of the created system have been tested on an array of sensors: a day/night vision camera with 1/3" CMOS/CCD light-sensor and AGC (Automatic Gain Control), a thermal imager FLIR TAU 2 with VOx (Vanadium Oxide) microbolometer light-sensor, an array of gas concentration sensors such as MQ6, MQ9, MG811.

Further research may relate to the following areas:

- although the methodology is proposed by the authors, it still needs further clarification on the topic of the link between FPV/VR/AR glasses and the camera gimbal for tracking in real-time the direction of the operator's head direction by the camera;
- it is promising to introduce technologies for recognizing dangerous situations (for example, fires or explosions) based on video signal processing using artificial intelligence technologies;
- it will also be rational to study the energy efficiency of the platform, energy saving, and rational distribution of power supply;
- further research on the stability of signal exchange between the mobile platform and the operator's console and increasing the range of distances where reliable communication operates should be mandatory.

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Contact information:

Oleksandr DOBRZHANSKYI, associate professor
Zhytomyr Polytechnic State University,
103 Chudnivska St., Zhytomyr 10005, Ukraine
E-mail: aikt_doo@ztu.edu.ua

Andrii TKACHUK, associate professor
(Corresponding author)
Zhytomyr Polytechnic State University,
103 Chudnivska St., Zhytomyr 10005, Ukraine
E-mail: aikt_tag@ztu.edu.ua

Anna HUMENIUK, associate professor
Zhytomyr Polytechnic State University,
103 Chudnivska St., Zhytomyr 10005, Ukraine
E-mail: gum_ann@ukr.net

Martin BOHDANOVSKYI, Senior Lecturer
Zhytomyr Polytechnic State University,
103 Chudnivska St., Zhytomyr 10005, Ukraine
E-mail: martin.bogdanovskiy@gmail.com

Vasyl BONDARCHUK, Senior Lecturer
Zhytomyr Polytechnic State University,
103 Chudnivska St., Zhytomyr 10005, Ukraine
E-mail: kvm_bvm@ztu.edu.ua

Ilona KRYZHANIVSKA, associate professor
Zhytomyr Polytechnic State University,
103 Chudnivska St., Zhytomyr 10005, Ukraine
E-mail: krilonika@gmail.com