Development of a Structural Control Scheme for a Small-sized Mobile Robot for Investigating Damaged Buildings

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***Abstract*:** The article deals with the development of a structural control scheme for a small-sized mobile robot designed for the investigation of damaged or destroyed panel buildings. The robot is equipped with ESP32-Cam hardware modules for real-time video transmission, L298N motor driver for motion control, DC converter for power stabilization and BMS 3S module for safe battery charging. Special attention is paid to the technical characteristics of the components, their interaction and influence on the overall performance of the system. The developed scheme ensures reliable and efficient operation of the robot in conditions of limited access and difficult navigation conditions, which is relevant in the context of the inspection of buildings after destruction caused by military actions.

***Keywords*:** mobile robot, block diagram, robot control, building research, ESP32-Cam, prefab buildings.

I. Introduction

The urgency of developing a structural scheme for controlling a small-sized mobile robot by a researcher is due to modern challenges associated with the need to inspect damaged buildings, in particular panel structures that have undergone significant destruction as a result of the military aggression of the Russian Federation. Panel houses, which are common in Ukraine, have a specific structure of large panel elements, which, in case of damage, can create a danger for conducting rescue operations or assessing the condition of the building. Due to weak connections between panels, even partial collapses can cause entire sections of the building to collapse, making it difficult to access areas requiring inspection. The use of small mobile robots allows for safe and efficient research in such areas, reducing risks for rescuers and engineers. Such robots are able to penetrate hard-to-reach places, monitor the condition of structures and transmit information for further analysis, which makes them indispensable in the process of surveying destroyed or damaged buildings in the conditions of modern conflicts.

II. STRUCTURE DIAGRAM OF THE MOBILE ROBOT

The control block diagram of a small-sized mobile robot for investigating destroyed or damaged panel buildings includes the use of hardware elements such as ESP32-Cam, L298N motor driver module, DC converter and BMS 3S module to charge three 18650 batteries. The main computing platform of the robot is ESP32-Cam, which not only provides control of the entire system, but also provides real-time video transmission for remote monitoring. The ESP32-Cam was chosen for its low cost, Wi-Fi support, and an integrated camera that allows the operator to see the robot's environment without the need for additional cameras. Its compact size and energy efficiency make it ideal for use in small mobile systems.

To control the movement of the robot, the L298N motor driver module is used, which can control two DC motors with a maximum voltage of up to 46V and a current of up to 2A per channel. This driver allows you to control the speed and direction of rotation of the motors, which is critical for maneuvering the robot in difficult environments, such as uneven or collapsed surfaces of damaged buildings. L298N has a reliable design that ensures stable operation even under conditions of increased load on engines.

The DC converter in the system is used to stabilize the voltage supplied to the motors and other elements of the system. Since 18650 batteries have a nominal voltage of about 3.7V, and the ESP32-Cam and L298N modules require a stable 5-12V to operate, using a converter allows you to provide the required voltage level. This is important to maintain the stable operation of the system during long-term use of the robot in research conditions.

The BMS 3S module for charging three 18650 batteries is chosen for its ability to ensure safe and efficient charging of the batteries, preventing them from overheating and over-discharging. This is critical for the autonomous operation of the robot in the field, where the lack of fast charging requires the most efficient use of energy. 18650 batteries ensure long-term system operation due to their high capacity and reliability.

Together, these hardware components provide effective control of a small-sized mobile robot capable of exploring damaged prefab houses, maneuvering in difficult environments, transmitting video information, and operating autonomously for long periods of time.

The developed structural diagram of the control of a small-sized mobile robot for the investigation of destroyed or damaged panel buildings is presented in Figure 1.

The developed structural diagram of a small-sized mobile robot for the investigation of destroyed or damaged panel buildings has a number of advantages compared to existing solutions. First of all, using the ESP32-Cam as the main module for video transmission and system control allows you to significantly reduce the cost of the robot without losing its functionality. Unlike more expensive platforms with separate cameras and transmitters, the ESP32-Cam integrates all the necessary components in one device, providing real-time video transmission over Wi-Fi. This allows you to quickly monitor the condition of the building without the need for complex and expensive solutions, such as professional drones or stationary inspection systems.

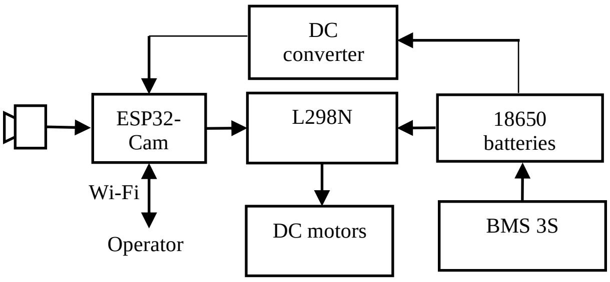

Figure 1– Structural diagram

Technically, the ESP32-Cam-based robot is light and compact, making it ideal for exploring hard-to-reach places in collapsed or unstable buildings. Thanks to the L298N motor control modules, the robot has the ability to precisely control the speed and direction of movement, allowing it to maneuver in difficult conditions where large and heavy platforms may not cope. In addition, DC motors provide high torque at low speeds, which is key for handling bumps or debris.

Compared to other solutions, this scheme provides long-term autonomous operation thanks to efficient power supply. Three 18650 batteries with a 3S BMS module guarantee a stable power supply and protection against overloads, which is important for work in field conditions where access to charging stations is limited. Compared to commercial work that uses more energy-intensive power systems, the proposed scheme provides better energy efficiency and operation duration, allowing research to be carried out for several hours without the need for charging.

From the technical side, the use of a DC converter allows you to adapt the battery voltage to the requirements of various system components, including engines and control modules. This makes it possible to efficiently use energy resources without losses and overheating. As a result, the developed scheme has significant advantages in terms of accessibility, compactness, energy efficiency and flexibility in use in damaged buildings where existing solutions may be cumbersome, expensive or less effective.

III. Conclusion

The proposed scheme is an effective and technologically sound solution for the investigation of destroyed or damaged panel buildings. The use of such hardware elements as ESP32-Cam, L298N motor driver, DC converter and BMS 3S module for 18650 batteries allowed to create a compact, economical and reliable platform that is able to perform tasks in difficult conditions. With the ability to transmit video in real time and support wireless communication, the mobile robot provides remote monitoring of the condition of structures, making it a valuable tool for engineers and rescuers.

The motion control efficiency of the L298N module allows precise control of speed and direction of motion, which is critical for maneuvering in uneven or congested building areas. 18650 batteries in combination with the BMS 3S module guarantee long-term autonomous operation and overload protection, which is an important advantage for working in conditions where access to charging stations is limited. At the same time, the use of a DC converter ensures a stable power supply to all components, which prevents system interruptions.

In general, the developed scheme of the mobile robot turned out to be more energy efficient, affordable and technically flexible compared to some existing solutions. Its compactness and functionality make it suitable for use in various conditions, in particular during research of damaged buildings, which is especially relevant in modern conditions of military operations. Prospects for the development of this scheme include the possibility of further improving the system by integrating additional sensors and algorithms to increase autonomy and accuracy of operation in difficult conditions.

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