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DESIGN AND PROGRAMMING OF A WALKING ROBOT

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Abstract: The paper presents the development of a walking robot. It describes the conditions that have to be fulfilled to achieve the robot's movement. The program aimed at controlling the robot is also described. The classification of mobile robots and the results of the robot operation verification are also presented in the article.

Keywords: gait control, hexapod robot, mobile robot, robot control, walking robot.

1. INTRODUCTION

Walking robots constitute a subgroup of mobile robots. Their characteristic feature is that they move using their legs. This type of movement is inspired by the motion of animals. That is the reason why walking robots are also classified as a group of nature-inspired robots. For example, in the project described in this article [Filipek et al. 2017], the leg is inspired by the structure of the Land Crab.

A project presented in this paper aimed to develop a six-legged walking robot, controlled remotely with the use of Bluetooth technology. The rest of the paper is organized as follows.

Section 2 describes the basic divisions of robots. In particular, attention has been focused on the distinction between wheeled and walking machines. Section 3 focuses on the presentation of the robot's construction process. It also includes an explanation of how the robot's movement has been implemented. Separate subsections focus on the characterization of the Bluetooth communication, as well as the control platform and the development environment. Section 4 includes a description of the tests carried out to verify the robot's operation. Finally, section 5 concludes the paper.

2. CIRCULAR AND WALKING ROBOTS

Mobile robots can be divided into wheeled and walking. The first group includes machines in which the locomotion used is entirely invented by man because no living organisms are known that move using wheels [Giergiel, Hendzel and Żylski 2020]. Robots using them typically have a minimum of three points of support, where movement is achieved by at least one of them (Fig. 1).

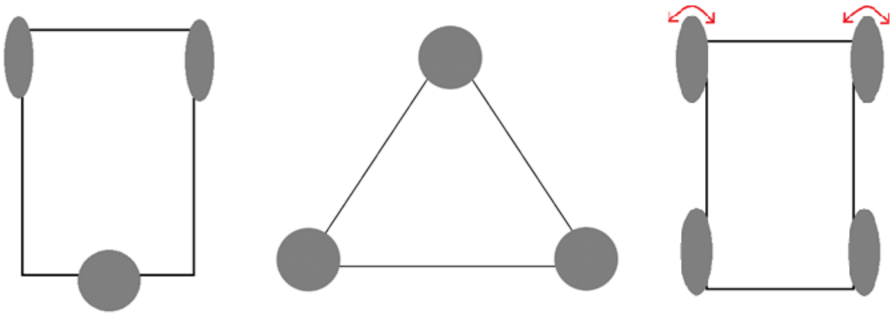

Fig. 1. Typical configurations of wheeled robots

Source: own study.

Tracks are another wheel drive commonly used in military services (Fig. 2). They are slower, less maneuverable, and also more expensive to produce, but they allow driving in places inaccessible to a typical wheel drive [Burdziński 1972].

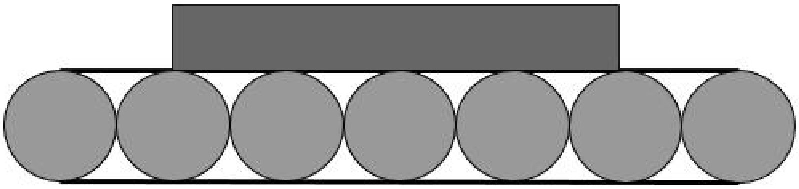

Fig. 2. Track model

Source: own study.

Walking robots use various types of movement that are inspired by nature as a means of transport. For example, four-legged machines are the result of observing terrestrial mammals, and six-legged are inspired by the motion of insects (Fig. 3). Compared to wheeled machines, an appropriate design allows them to move on more difficult terrain [Todd 1985].

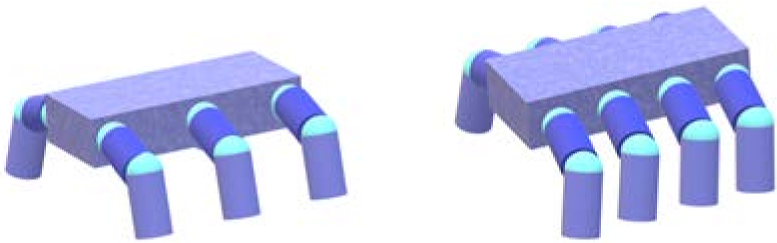

Fig. 3. Examples of walking robots

Source: own study.

A state-of-the-art hexapod walking robot was presented in [Tedeschi and Carbone 2014]. The design, simulation, and control of a hexapod robot using MATLAB software are introduced in [Urrea, Valenzuela and Kern 2016]. An example of a hexapod robot design, where a CPLD is used to control the servomotors, is presented in [Pa and Wu 2012]. In [Ali et al. 2013] the FPGA is used for servo motor control in a six-legged robot platform. Other recently introduced solutions concerning the design and control of a walking robot can be found in [Hwang et al. 2019] and [Žák, Rozman and Zbořil 2021].

3. ROBOT CONSTRUCTION

This section describes the components of the robot and its properties.

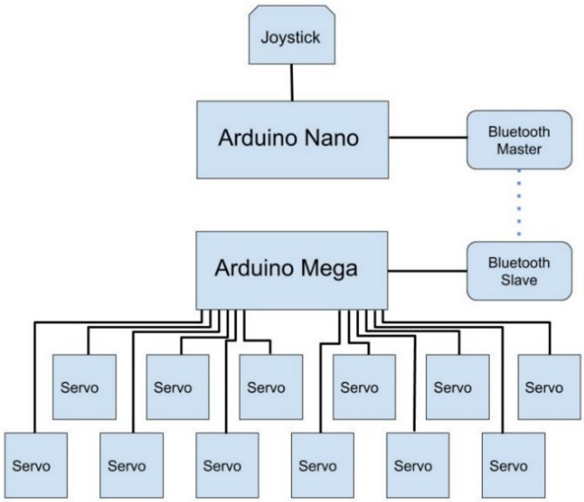

Fig. 4. A block diagram of the walking robot control system

Source: own study.

3.1. Assumptions

The assumptions defined at the beginning of the project realization stated that the robot will have six legs. Each of these consists of two servos, thanks to which the limb can rise, fall, and move left and right [Ben-Ari and Mondada 2018]. Two Arduino modules were used for the construction of the robot's control system. Communication was carried out using Bluetooth technology, using HC-05 modules. The skeleton was built using parts from the Velleman Allbot kit and a joystick was used to set the direction of the robot's movement. Changing the position of the joystick, thanks to the Arduino and Bluetooth modules, leads to the movement of the servomotors. The control system was designed to achieve a stable movement of the robot on even surfaces and with small faults.

Figure 4 shows a block diagram of the walking robot control system.

3.2. Walking robot control system

Two Arduino modules were used in the presented project to remotely control the robot's movement. The board used in the control platform should be able to connect to a Bluetooth module and a joystick should be used for this task while maintaining small dimensions. These requirements are met by the Arduino Nano. To build the robot, a board that allows connecting at least twelve servos was also needed, as well as a Bluetooth module. Another requirement was the compatibility with the components of the Allbot set that were used in the construction of the robot. Taking the above-mentioned requirements into account, it was decided to use the Arduino Mega system. The software for the robot was developed using the C programming language.

3.3. Bluetooth module

For the robot to meet the mobility assumption, it was necessary to use wireless communication. After exploring possible options, a decision was made to use Bluetooth technology [Gajewski and Wszelak 2020]. The HC-05 module was selected for use, enabling it to be programmed both as a master unit and as a slave unit. Communication between the modules is possible over a distance of up to ten meters in the Bluetooth 2.0+ EDR standard. Its reprogramming is done with AT commands, which allow, among other things, to change the name and operating mode [Heydon 2012].

3.4. Control platform

The control platform consists of the Arduino Nano system responsible for processing the information received from the joystick and transmitting it to the Bluetooth module, where it is then sent to the robot (Fig. 5).

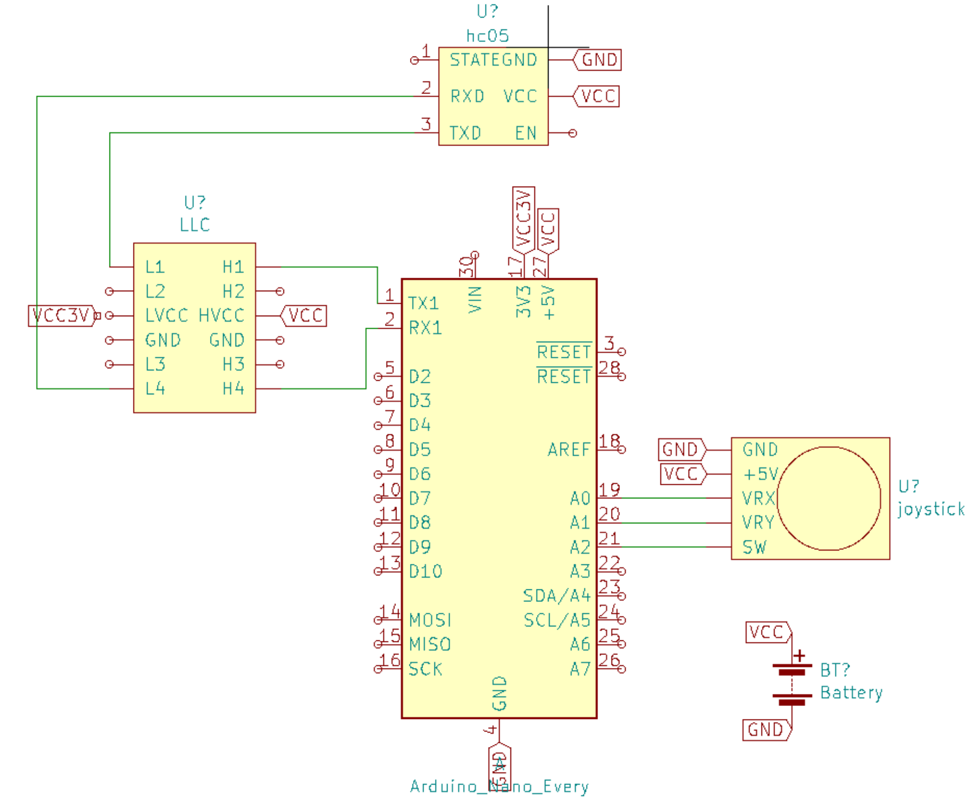

Fig. 5. Control platform connection diagram

Source: own study.

The whole process begins with reading the values of the deflections on the OX, OY, and OZ axes. Each of them is responsible for different commands. Pressing the button changes the value on the OZ axis, which sends the "wave" command, which is a priority. It is composed of raising and lowering a limb several times as if the robot "greeted" the person standing in front of it. Its call sign is 1. For the remaining deflections, a special algorithm has been applied, which is to compare them and select those for which the values differ most from the zero point of the joystick position. Thus, neither of the OX and OY axes has a priority. This prevents a situation in which, although the joystick is strongly deflected to one side, the control platform will send the command for the second indication slightly deflected beyond the zero point. If the position of the controller is not changed, the return values are approximately 512, and when the position is forced, the received numbers are between 0 and 1012.

The OX axis is responsible for the longitudinal movement of the robot. Deflecting the joystick towards "zero" will send the command "forward", the call sign of which is 2. If the returned values are closer to the number 1024, the execution module will receive the digit 3, meaning "back".

A similar algorithm was developed for the OY axis responsible for the torsional movement of the machine. When the joystick deflection returns numbers close to zero, the left command is sent, which corresponds to the character 4 (Fig. 6). If the controller reposition is in the other direction, the command sent to the robot will force the machine to move to the right. The number 5 corresponds to this command. [Raczyk, Sobiech and Piotrowski 2016].

The mutual relations between the command names and the corresponding characters are described in Table 1.

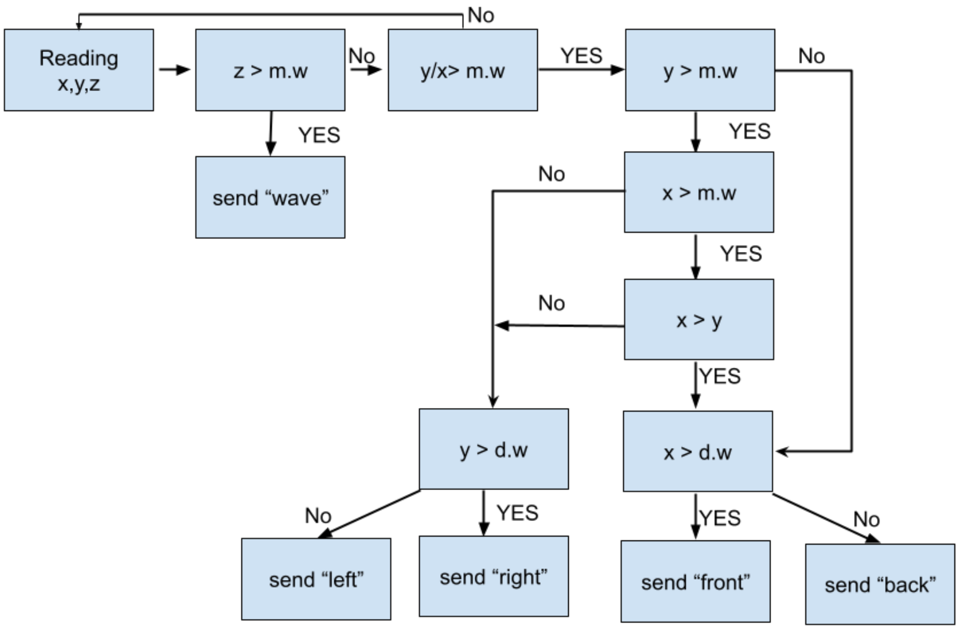

Fig. 6. A flowchart of the algorithm for the robot's control

Source: own study.

Table 1. Relations between the command names and the corresponding characters

Corresponding characters	Command names
1	Wave
2	Front
3	Back
4	Right
5	Left

Source: own study.

3.5. Execution platform

The execution platform consists of the Arduino Mega, a Bluetooth module, twelve servos, and parts from the Allbot kit.

Figure 7 shows how these elements are connected with each other.

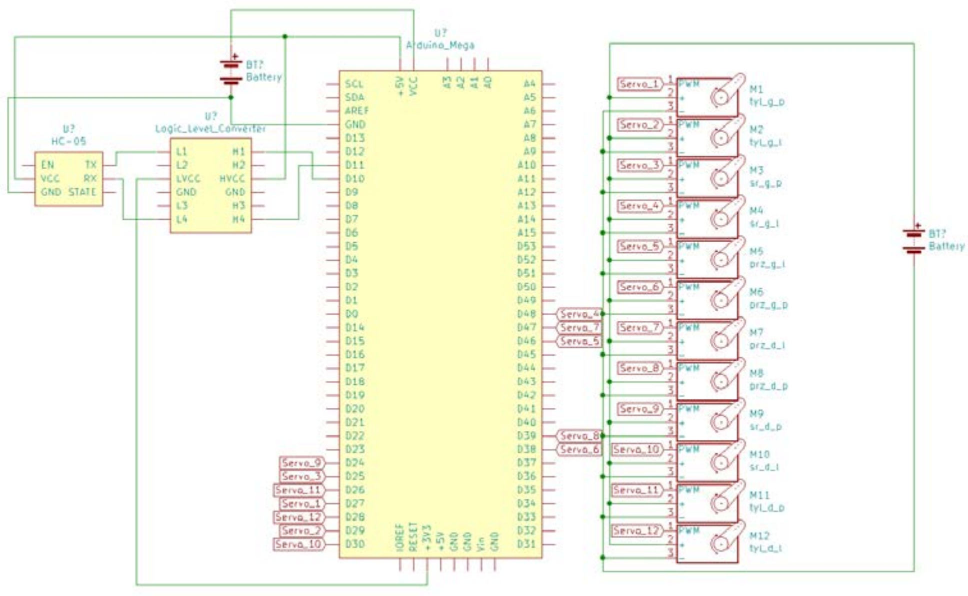

Fig. 7. Execution platform connection diagram

In addition to the skeleton, they also include plates for connecting actuators and batteries. This entire system is responsible for receiving information from the control platform and executing the appropriate command. Depending on the digit sent, an appropriate sequence of movements is performed using the *switch* ... *case* statement. To prevent the robot from tipping over, the limbs were divided into two groups according to the principle that the legs belonging to a given group are separated by the greatest distance allowed by the structure (Fig. 8). In each group, the servos responsible for the same movements (left-right or up-down) perform the same movements simultaneously (Fig. 9). The robot is designed to perform five sequences of movements: swing, forward, backward, left, and right [Spong and Vidyasagar 1997; Kozłowski, Dutkiewicz and Wróblewski 2019]. Thanks to this, it can move in any direction.

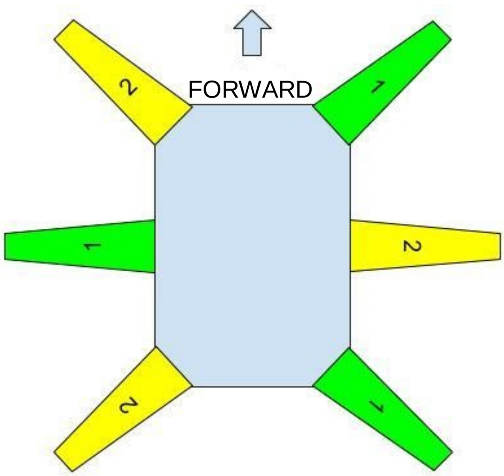

Fig. 8. Division of the legs into groups

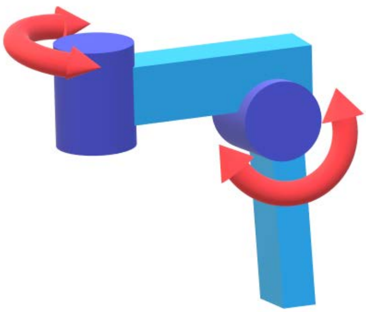

Fig. 9. Servos in the leg

4. VERIFICATION OF THE ROBOT'S OPERATION

In order to verify the operation of the robot, it was subjected to three tests: checking the pairing time of the modules, the time needed for the information from the joystick to force the sequence, and determining the height of the jumps that the machine could overcome.

The first attempt was to turn on the power supply for the systems three times and determine how many seconds were needed to establish communication. The average time for this experiment was set at 5.8 seconds. On this basis, it can be concluded that it is desirable to improve this result. The time needed to establish communication was long, but when the modules paired, the commands were sent immediately, without causing any further delays.

The next test consisted of eight trials. For each of them, the time elapsed from the moment of forcing the position change on the joystick to the initiation of the robot's movement was measured, the average of which was less than 0.5 seconds. The obtained result is satisfactory because the reaction to the forced change of the position of the controller was immediate.

The last test was to find out which jumps the robot could overcome. Obstacles of different heights were set up using a stack of sheets of paper. After the tests, it was found that the robot was able to overcome a step up to a maximum height of half a centimeter, and down to a centimeter. The influence of the type of surface on the mobility of the robot was also observed. On slippery ground, the legs of the machine lost traction, so instead of moving the body, they moved in one place.

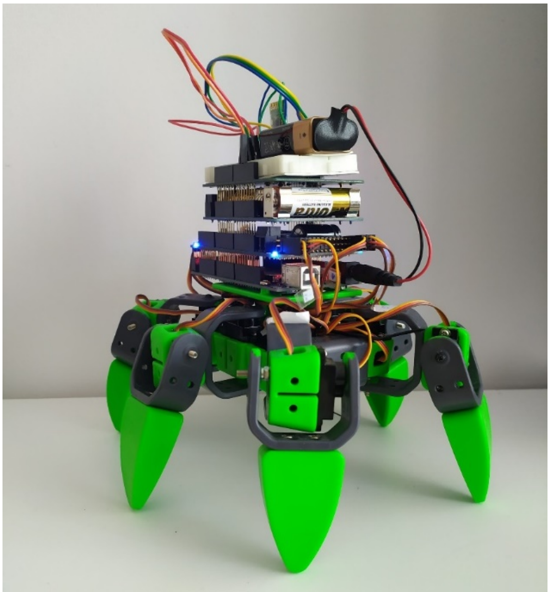

Fig. 10. The final construction of a hexapod robot

5. CONCLUSIONS

The paper describes the design of a six-legged walking robot, remotely controlled using Bluetooth technology. The machine was designed, as well as the control module, for which special software was developed. The Arduino chip, Bluetooth communication, and parts from the Allbot kit were used, and the developed robot moves in four directions. Displacement is realized employing six legs, each of them being a system with two degrees of freedom (Fig. 10). The machine is controlled by a joystick.

Further works will include the application of a mechanism enabling the robot to avoid obstacles. It would also be useful to make the joystick deflection dependent on the speed at which the robot would move.

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