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Movement Control System of 3-DOF Quadruped Robot

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Abstract – **Robotics technology has been used in various aspects of life to make work easier. In the industrial sector, robots are used to replace human roles in order to produce more effective and efficient work. The use of robots is also carried out in jobs with a high level of risk, one of which is search and rescue (SAR). In its development, the use of robots for SAR requires high flexibility and effectiveness in carrying out movements for finding and extinguishing hotspots as well as rescuing victims. So, in this research, a movement control system will be designed for a legged robot. The robot's design consists of four legs. Each leg of the robot is integrated with three servo motors, so that each leg movement will have three degrees of freedom. Tests are carried out to determine the speed of the robot in various directions of movement by changing the rotation angle of the servo on each leg. The test results show that a legged robot can accelerate at a maximum speed of 0.066 m/s.**

Keywords: robot, SAR, legged robot, speed, servo

I. Introduction

Science and technology (IPTEK) in the era of the Industrial Revolution 4.0 are developing very rapidly. Products developed by science and technology play a very important role in various aspects of life, such as in the fields of education, medicine, industry, fisheries, agriculture, and others. The use of this technology encourages the transformation process of all activities carried out by humans traditionally towards a more modern direction, so that the work done can be more effective and efficient [1]. Robotics is one of the topics of concern for researchers in universities and industry. In the industrial field, robots are the main choice to replace several human roles. The work produced by robots is more specific and structured, with shorter processing times compared to human labor [2]. One type of robot that is used in the industrial field is a legged robot. This robot has a high degree of flexibility in its movement. The advantage possessed by legged robots is that they can move on uneven terrain. although acceleration is still lower when compared to wheeled robots [3].

The use of legged robots for SAR (search and rescue) activities has been developed by several researchers in several prototype forms. One of its uses is for firefighting activities [4]. The problem faced in designing a legged robot is the speed of the robot in maneuvering, so in this study, a 3-DOF quadruped robot will be designed to test the speed of the robot in various directions of movement.

A legged robot is a robot that moves and maneuvers using artificial legs that are driven by servos. The number of robot legs used varies depending on the situation.Based on the number of legs used, legged robots can be divided into several types, namely two-legged robots (humanoid robots), three-legged robots (tripod robots), four-legged robots (quadruped robots), six-legged robots (hexapod robots), and other multi-legged robots [5]. The mechanical form of a legged robot is usually shaped to resemble the legs of an insect or other animal. In operation, the movement of a legged robot often encounters obstacles when maneuvering in a room with a certain distance; this is due to the fact that in the step movement, the legged robot does not use a closed-loop control system that has feedback [4].

One of the implementations of the legged robot is a firefighting robot. Firefighting robots are one of the divisions contested in the Kontes Robot Indonesia (KRI). Starting in 2021, this division is known as the Kontes Robot SAR Indonesia (KRSRI) [6]. In its application, a legged robot maneuvers in a maze to find fire points. The use of legged robots has an advantage compared to using wheeled robots because they can pass through uneven surfaces. The use of more legs in legged robots makes it possible to perform more movements. The number of degrees of freedom on each leg has an influence on the robot's flexibility in maneuvering. But the use of more legs requires more power because the servo used to move the robot's legs is getting bigger. The algorithms used in the movement of robots with many feet are also more complex. [7-8].

Figure 1. Legged Robot

II. Method and Design

In this study, the design of the legged robot was carried out. The four-legged robot designed is a quadriplegic with three degrees of freedom (DOF). Each robot leg will be integrated with three servos, so that each foot movement will have three degrees of freedom. This research consists of three stages, namely hardware design, software design, and mechanical design. In hardware design, the tools and components used consist of an Arduino Nano, a servo motor, a PS2 joystick, a push button, and a step-down XL4015. Software design for microcontroller devices is carried out using the Arduino IDE to give commands to the hardware that has been designed. The mechanical system of the legged robot is designed using 3D printing. In general, the system diagram block is shown in Figure 2.

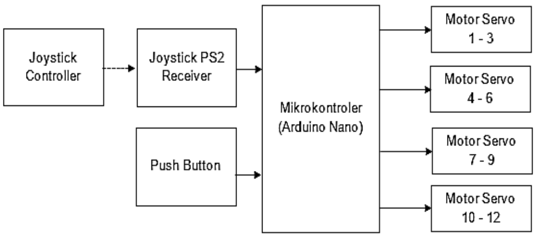

Figure 2. Block Diagram of a Legged Robot

A legged robot that is controlled using two methods The robot can be controlled remotely by using a joystick that is wirelessly connected. In addition, the robot can be moved using a push button attached to its body. For wireless control systems, movement instructions given on the joystick will be sent to the receiver integrated with the microcontroller device. The microcontroller will process the received data and transmit an actuation signal to drive the servo motor.

Data collection is carried out by testing the speed of the robot on various variations of mileage. This test was performed using various variations in the distance between the left and right legs through the servo angle setting.

Figure 3. Legged Robot Construction

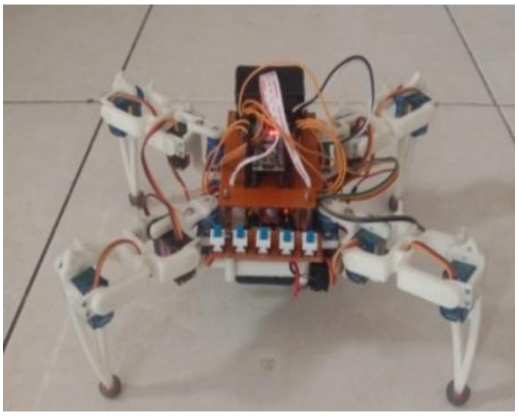

Figure 4. Four-Legged Robot Design

III. Results and Discussion

A. *Forward Movement*

Testing in this study is divided into several stages. In the first stage, testing the forward movement of the legged robot was carried out. This test was carried out to observe the acceleration of the robot when carrying out forward movements. The robot will be driven using a push button with various variations in mileage. The speed of the robot is calculated from the data on the mileage and the time it takes for the robot to reach the distance.

In this first stage of testing, treatment was given in the form of a change in the distance between the left and right legs by changing the angle of rotation of the servo on each leg. This test was performed using three different distances between different legs. Test results are shown in Tables 2–4.

Table 1. Robot Leg Servo Angle Setting

Test	Servo Angle			
	Leg 1	**Leg 2**	**Leg 3**	**Leg 4**
First Test	90°	90°	90°	90°
Second Test	95°	95°	85°	85°
Third Test	85°	85°	95°	95°

Table 2. Results of the Forward Movement Test - First Test

Distance (m)	Velocity (m/s)			
	Data 1	Data 2	Data 3	Average
0,4	0,039	0,038	0,038	0,038
0,8	0,043	0,048	0,038	0,043
1,2	0,043	0,042	0,045	0,043
1,6	0,042	0,046	0,047	0,045
2	0,049	0,046	0,050	0,048
2,4	0,053	0,044	0,050	0,049
2,8	0,050	0,050	0,050	0,050
3,2	0,053	0,053	0,053	0,053
3,6	0,059	0,059	0,059	0,059
4	0,066	0,066	0,066	0,066

Table 3. Results of the Forward Movement Test - Second Test

Distance (m)	Velocity (m/s)			
	Data 1	Data 2	Data 3	Average
0,4	0,029	0,031	0,030	0,030
0,8	0,038	0,037	0,036	0,037
1,2	0,038	0,042	0,042	0,041
1,6	0,040	0,040	0,042	0,041
2	0,041	0,043	0,044	0,043
2,4	0,042	0,041	0,052	0,045
2,8	0,046	0,046	0,046	0,046
3,2	0,052	0,053	0,053	0,053
3,6	0,059	0,059	0,059	0,059
4	0,066	0,066	0,066	0,066

Table 4. Results of the Forward Movement Test - Third Test

Distance (m)	Velocity (m/s)			
	Data 1	Data 2	Data 3	Average
0,4	0,031	0,031	0,032	0,031
0,8	0,035	0,033	0,034	0,034
1,2	0,041	0,038	0,039	0,039
1,6	0,042	0,039	0,039	0,040
2	0,047	0,037	0,042	0,042
2,4	0,047	0,039	0,039	0,042
2,8	0,043	0,046	0,046	0,045
3,2	0,053	0,053	0,053	0,053
3,6	0,059	0,059	0,059	0,059
4	0,066	0,066	0,066	0,066

Based on the test results of the three test scenarios that have been carried out for forward movement, it can be seen that the longer the distance traveled, the higher the average speed generated by the robot's movement, as shown in Figure 5. The movement of the robot with a servo angle setting on the leg perpendicular to the robot or at a 90-degree angle results in greater speed than other test scenarios. From several tests carried out, the top speed achieved was 0.066 m/s, and the lowest speed was 0.029 m/s.

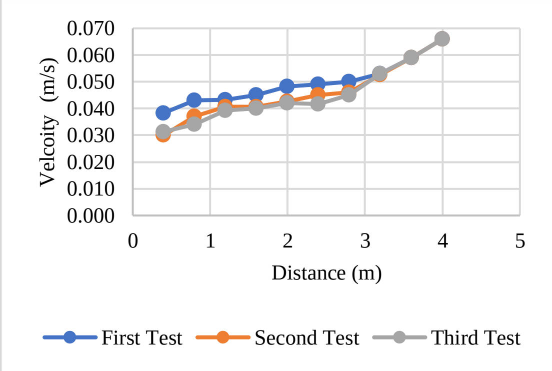

Figure 5. Graph of Legged Robot Forward Movement Speed

B. *Backward Movement*

Backward movement testing on legged robots has the same method as forward movement testing. This test is carried out to observe the acceleration of the robot when carrying out reverse movements. The speed of the robot can be calculated from the data on the mileage and the time it takes for the robot to reach the distance.

In this second stage of testing, treatment was given in the form of a change in the distance between the left and right legs by changing the angle of rotation of the servo on each leg, as shown in Table 1. This test was performed using three different distances between different legs. Test results are shown in Tables 5–7.

Table 5. Results of the Backward Movement Test - First Test

Distance (m)	Velocity (m/s)			
	Data 1	Data 2	Data 3	Average
0,4	0,039	0,038	0,038	0,038
0,8	0,048	0,045	0,048	0,047
1,2	0,049	0,044	0,053	0,049
1,6	0,051	0,051	0,052	0,051
2	0,052	0,054	0,054	0,053
2,4	0,053	0,051	0,056	0,053
2,8	0,053	0,054	0,054	0,054
3,2	0,055	0,054	0,056	0,055
3,6	0,059	0,059	0,059	0,059
4	0,066	0,066	0,066	0,066

Table 6. Results of the Backward Movement Test - Second Test

Distance (m)	Velocity (m/s)			
	Data 1	Data 2	Data 3	Average
0,4	0,038	0,037	0,033	0,036
0,8	0,042	0,040	0,042	0,041
1,2	0,042	0,042	0,047	0,044
1,6	0,046	0,049	0,048	0,048
2	0,047	0,048	0,046	0,047
2,4	0,048	0,048	0,047	0,048
2,8	0,049	0,046	0,049	0,048
3,2	0,053	0,053	0,053	0,053
3,6	0,059	0,059	0,059	0,059
4	0,066	0,066	0,066	0,066

Table 7. Results of the Backward Movement Test - Third Test

Distance (m)	Velocity (m/s)			
	Data 1	Data 2	Data 3	Average
0,4	0,034	0,036	0,034	0,035
0,8	0,038	0,04	0,036	0,038
1,2	0,035	0,04	0,038	0,038
1,6	0,042	0,043	0,039	0,041
2	0,047	0,042	0,041	0,043
2,4	0,049	0,047	0,047	0,048
2,8	0,047	0,046	0,046	0,046
3,2	0,053	0,053	0,053	0,053
3,6	0,059	0,059	0,059	0,059
4	0,066	0,066	0,066	0,066

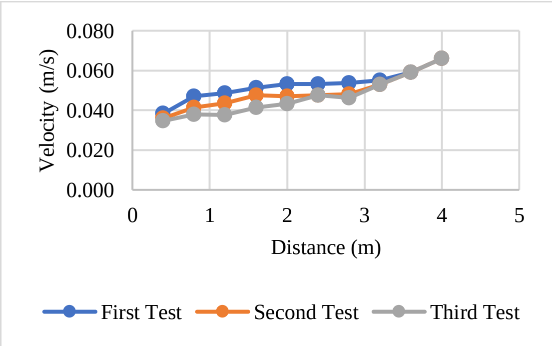

Figure 6. Graph of Legged Robot Backward Movement Speed

Based on the test results of the three test scenarios that have been carried out for reverse movement, it can be seen that the longer the distance traveled, the higher the average speed generated by the robot's movement, as shown in Figure 6. The movement of the robot with the servo angle setting on the leg in the third test scenario resulted in a greater speed than other test scenarios. From several tests carried out, the top speed achieved was 0.066 m/s, and the lowest speed was 0.033 m/s.

C. *Left and Right Movement*

Left and right movement testing is carried out to observe the time it takes for a legged robot to rotate 90 degrees towards the left or right from the starting position. In this second stage of testing, treatment is given in the form of a change in the distance between the left and right legs by changing the angle of rotation of the servo on each leg. Test results are shown in Tables 8–10.

Table 8. Right Movement Test Results

Test	Time (s)		
	First Test	Second Test	Third Test
1	9,68	9,76	11,34
2	9,6	9,23	10,91
3	9,76	10,11	9,69
4	9,78	9,72	9,93
5	9,42	10,12	10,51
6	10,02	10,28	10,66
7	10,99	10,62	9,95
8	10,43	10,20	10,56
9	10,95	10,31	11,23
10	10,15	10,37	11,82
Average	10,08	10,07	10,66

Table 9. Left Movement Test Results

Test	Time (s)		
	First Test	Second Test	Third Test
1	9,38	11,17	14,42
2	10,41	12,88	14,88
3	10,48	12,56	15,29
4	10,33	11,64	12,62
5	10,07	12,83	12,11
6	9,58	12,12	14,14
7	10,33	12,79	13,74
8	10,01	12,22	13,47
9	10,15	12,86	13,54
10	10,13	12,42	13,01
Average	10,09	12,35	13,72

Based on the results of tests conducted for left and right movement, the collected data shows that movement to the left takes a longer time when compared to movement to the right. The average time required for a movement to the left is 12.05 minutes, while for a movement to the right, it takes an average of 10.27 minutes.

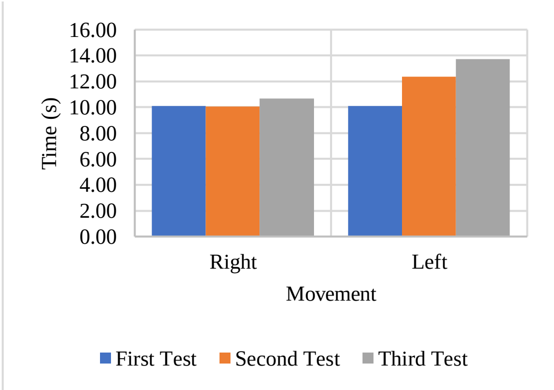

Figure 7. Graph of Left and Right Legged Robot Response Time

IV. Conclusion

The quadruped robot that has been designed can maneuver in various directions of movement. The movement of the robot is controlled by means of a push button. The test results showed that the movement of the legged robot to advance and reverse with a servo angle setting on the leg perpendicular to the robot or at a 90-degree angle resulted in greater speed than other test scenarios. In this test, the top speed obtained was 0.066 m/s.

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