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Design and implementation of robotank for room monitoring and exploration

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Abstract — A robot is a mechanical device that can perform physical tasks autonomously or with human control. Robots began to be used for monitoring in areas that have narrow spaces and/or dangerous areas. This robot must be able to carry out monitoring with a remote control system. Therefore, in this study, a robotank is designed that can perform space exploration with remote control. Robotank is designed to use a track and wheel that can pass through various terrains, and it has dimensions of 11.8 x 10.8 x 9.1 cm. Robotank is equipped with a camera to monitor in real-time. Robotank can move from one point to another by controlling using a remote control system with a maximum distance of 20 meters in line of sight terrain and 16 meters in non-line of site fields, with an average speed of 0.84 m/s. Robotank can work for 1 hour 52 minutes. This robotank is hoped to be used to explore areas or rooms with small spaces and is dangerous.

Keywords – robotank, exploration, camera, monitor

I. INTRODUCTION

Currently, there are many technologies in the field of robotics that are made to help humans work [1]. However, with the limited space for humans to monitor areas that have small space, cannot be passed by humans, and areas that are quite dangerous, it is necessary to design a robot that can carry out exploration and monitoring remotely [2]. In other term, it can be called a teleoperation robot [2]. This robot has been commonly used in the military, security, mining, agriculture, fisheries, tourism, and photography.

Teleoperation robots have been widely used for observation and exploration of limited or hard-to-reach areas for humans. Exploration areas include air, water or underwater, and land [3]. Telerobot, which is used for area monitoring by air, is proposed in the study [4], [5]. This robot became known as the unmanned aerial vehicle (UAV) and was widely used for aerial photography, area mapping, and air pollution monitoring. Telerobot development for underwater exploration, which has recently been widely applied, is the autonomous underwater vehicle (AUV). AUV application for exploration of underwater conditions is proposed in the study [6]–[8]. In practical terms, AUVs have been used in underwater rescue in the event of a transportation accident [9]. Meanwhile, the development of land exploration robots has also received more attention from researchers. This robot is widely used to observe dangerous and narrow spaces, such as spaces with dangerous gases or spaces suspected of having explosives material. Mobile robots generally walk using leg or wheel mechanics [10], [11]. Mobile robots which use legs tend to be more complex in component installation, and other issues are stability and speed [12], [13]. Therefore, mobile robots with wheel mechanics are more commonly used to solve these problems. However, mobile robot wheels have disadvantages: the limited turning radius to pass through a very narrow area. The mobile robot can adopt the wheel mechanics used by the tank to overcome the current issue.

This study proposes a mobile robot that can be used for monitoring narrow areas or spaces. The mechanical working wheel adopts the tank wheel mechanic. This robot is then called robotank. Robotank is designed to use a track and wheel that can pass through various terrains, and it has dimensions of 11.8 x 10.8 x 9.1 cm. Robotank is equipped with a camera video to monitor the surrounding area in real-time. Robotank can move from one point to another by controlling using a remote control system

As a reminder, this paper is structured as follows. Section one presents a brief overview of the teleoperation robot, the problem, and the proposed solution. Furthermore, section two presents a brief explanation of the model and implementation of the proposed system. Section three presents the results and is followed by a discussion of the proposed system. Finally, a brief conclusion and implication of this study are presented in the last section.

II. RESEARCH METHODS

A. Tank Robot

The robot is a mechanical device that can perform physical tasks, either using human supervision and control or using predefined programs (artificial intelligence) [14]. Tank robot, in this study then called a robotank, is a robot with characteristics like a tank that uses a motor actuator and a trackwheel to move the robot's entire body so that the robot can move from one point to another. The advantage of the track wheel on a tank robot allows the robot to move more smoothly and go through various fields. Robotank developed in this study consists of two main parts, including the tank robot control and tank robot mechanics, as shown in Fig.1.

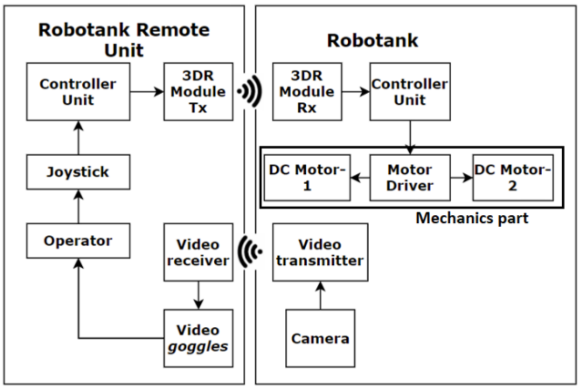


Fig. 1. Proposed system

B. Robotank Control Systems and Components

Figure 2 illustrates the diagram of controllers and robotank. The communication medium used is the 3DR Telemetry module. If the main microcontroller unit on the robotank gets instructions from the joystick, the microcontroller system will immediately execute the instructions to move the wheels. The device functions are as follows:

a) Power Source

The power supply serves as a source of energy. In this study, the power source uses a LiPo 7.4 Volt/1000 mAh battery.

b) Joystick

The joystick function is an input to control the robotank. It gives the robotank to move in various directions. In this study, a potentiometer-based Joy Stick PS2 KY-023 module was used, which was then integrated with Arduino to estimate the direction of the joystick movement.

c) Main Controller Unit

The Main Controller Unit is a microcontroller that controls all the systems, reading input and executing the commands. Arduino UNO with ATMEGA 328 controller base is used as the main control of the robot.

d) 4. 3DR Telemetry Module

3DR Telemetry consists of 2 devices, namely 3DR Transmitter and 3DR Receiver, where 3DR Telemetry functions as a communication bridge between the tank robot controller and the tank robot.

e) Motor Driver

The motor driver functions to drive the DC motor where the direction of the motor changes depending on the instructions given from the joystick. A motor driver module with an L298N chip is used in this study to control two DC motors.

f) DC motor

The DC motor function is a wheel drive, where the wheels move in the direction instructed. In this study, the robot tank uses two mini DC motors with an operating voltage of 3-6 volts connected to a wheel belt.

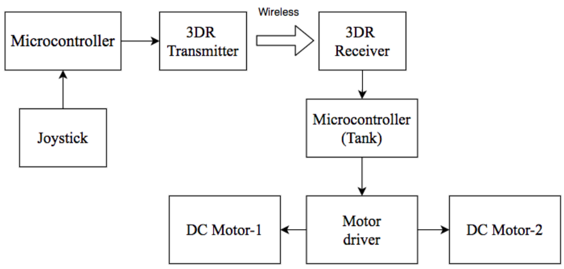


Fig. 2. Diagram of controllers and robotank

From Fig. 2, it is known that the mechanical needs of the robot tank include a control system, DC motor, motor driver, and robot chassis. With an estimated budget of less than 500,000 in rupiahs.

C. Design of Monitoring System using Camera

The monitoring system consists of the components, as shown in Fig. 3.

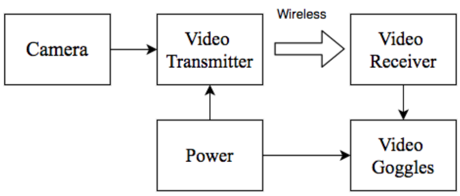


Fig. 3. Diagram of the monitoring system

From Fig. 3 it can be illustrated how the monitoring system by robotank works. First, the installed camera will send video data using a video transmitter that the video receiver receives and displays the video sent directly on the goggle video.

D. The Workflow of Proposed System

Figure 4 below is a workflow in sending and receiving commands to robotank,

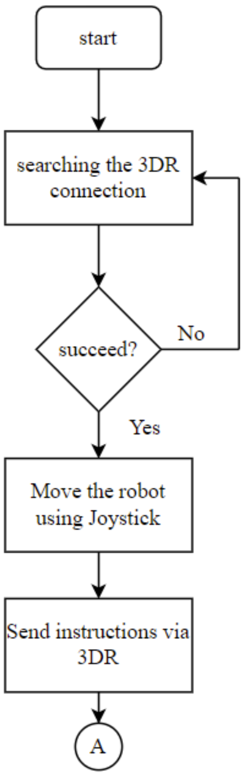


Fig. 4. Flow chart of the instruction transmission process

From Fig. 4 several commands can be sent via the joystick. These instructions consist of:

1. Joystick is moved up = Forward Robot (F)
2. Joystick is moved to the right = Robot turns right (R)
3. The joystick is moved to the left = Robot turns left (L)
4. Joystick is moved down = Robot reverse (B)

After sending the instruction and the joystick is idle, the instruction sent is for the robot to stop (S). Although this is intended to keep communication between the two devices running, the process will be carried out continuously looping.

Figure 5 is the response after sending instructions, where the response can be executed as follows:

1. F = Robot forward (dc motor-1 and dc motor -2 move forward)
2. R = Robot turn right (motor dc-1 forward and motor dc-2 reverse)
3. L = Robot turn left (motor dc-1 reverse and motor dc-2 forward)
4. B = Robot reverse (motor dc-1 and motor dc-2 move backward)
5. S = Robot stop (dc motor-1 and dc-2 motor stop)

In general, if the instruction from the joystick is F, the instruction will be processed in the microcontroller, which is then forwarded to the 3DR TX to be sent. This instruction will be received by the 3DR RX, which is then processed in Arduino to read the instruction, after the instruction is read, the dc-1 motor and dc-2 motor will immediately move forward. The wiring diagram of joystick module with Arduino and its design are shown in Fig. 6.

Meanwhile, the program code to read the direction of the joystick and motor control is as follows.

```
//Initiation Button input and output pin
int button=3;
int sw;
const int x_axis = 0;
const int y_axis = 1;
const int motor1 = 4;
const int motor2 = 5;
int hor=0;                  //horizontal mov
int ver=0;                  //vertical mov
int a=0;

void setup() {

pinMode(button, INPUT);
digitalWrite(button,HIGH);
pinMode(motor1,OUTPUT);
pinMode(motor2,OUTPUT);
}

void loop() {
sw = digitalRead(button);//read button pin D3
if(sw==LOW)
          {
          a++;
//read pin ADC right or left
          if (a==1){while(1){
                 hor= analogRead(x_axis);
                 hor= map(hor,0,1023,255,0);
                 analogWrite(motor1, hor);

                 ver = analogRead(y_axis);
                 ver= map(ver,0,1023,255,0);
                 analogWrite(motor2, ver);

                  sw=digitalRead(button);
                 if(sw==LOW){break;}
                  }
          }
//read forward or back
        if (a==2)
              {
                hor=0;
                analogWrite(motor1, hor);

                ver=0;
                analogWrite(motor2, ver);
                a=0;

                }


    }
  }
```

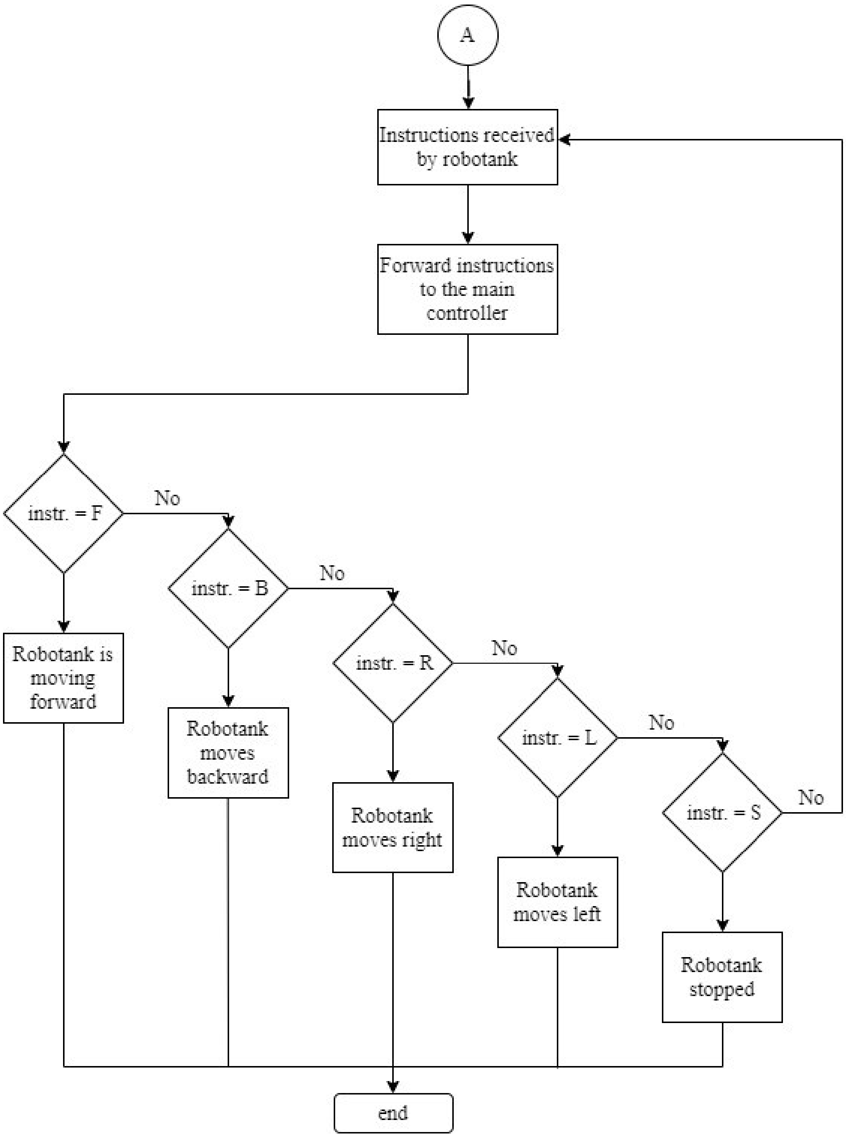
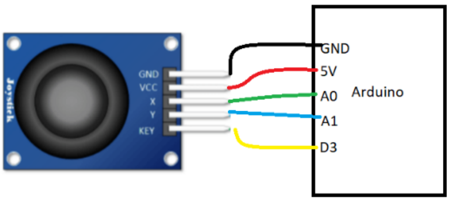


Fig. 5. Flow chart of instruction execution



(a)

(b)

Fig. 6. Joystick for robot movement control (a) wiring diagram (b) implementation

E. The Workflow of the Monitoring Sub-System

The video capture process will run when the video transmitter (VTX) and video receiver (VRX) connect. After the connection is established, the video taken from the camera will be displayed on goggles video in real-time. The process is carried out continuously. The details of the workflow of the monitoring system are shown in Fig. 7.

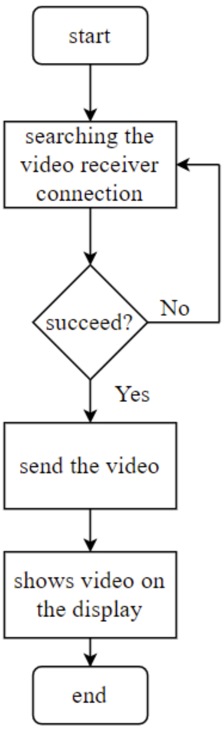


Fig. 7. The workflow of the monitoring sub-system

F. The Chassis of Robotank and Video Viewer

Robotank mechanics using the Mini RobotShop Rover Chassis [9]. The platform has dimensions of 10.5cm (W) x 11.5cm (L) x 4.5cm (H) and weighs 135g. It has a belt drive component to drive the front and rear wheels. The chassis of the robotank is shown in Fig. 8.

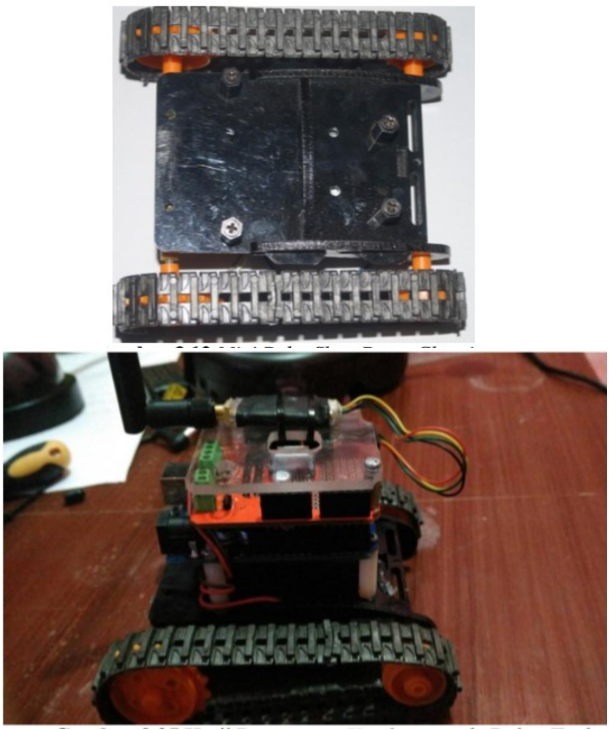


Fig. 8. The chassis of the robotank

Meanwhile, to display the video, a Fatshark teleporter can view live broadcasts by placing a wireless camera on the robotank. This module will send data in the form of video to the receiver on the Fatshark goggles. It uses a circular polarized SpiroNet antenna with a frequency of 5.8Ghz. The installation of the transmitter and receiver video recorder on a robotank is shown in Fig. 9.

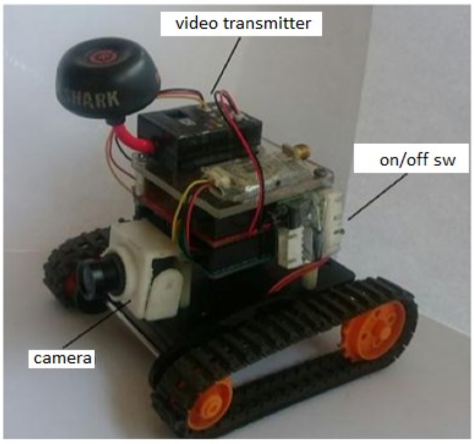


Fig. 9. Video recorder installation on a robotank

III. RESULTS

In the previous section, we discussed in detail the realization of the mechanics and control systems of robotank. The next stage tests the proposed system. It includes the control distance, video transmission distance, speed, and the maximum duration of the robot's work. Details of each test result followed are presented in the following subsection.

A. Control Distance Testing

Testing the robotank control distance aims to determine how far the communication between the controller and the robot can be carried out. In this case, the measurement is performed in Line of Sight (LOS) and Non-LOS conditions. The test results for each of these scenarios are presented in Table 1 and Table 2.

Table 1. The results of the control distance test in LOS conditions

Distance (m)	Condition of robotank
5	controlled
10	controlled
15	controlled
20	controlled
25	cannot be controlled
30	cannot be controlled

Table 2. The results of the control distance test in Non-LOS conditions

Distance (m)	Condition of robotank
5	controlled

Distance (m)	Condition of robotank
10	controlled
16	controlled
20	cannot be controlled
25	cannot be controlled
30	cannot be controlled

B. *Video Transmission Distance Testing*

This test aims to determine the maximum distance between the video transmitter and the video receiver on video goggles where the image quality is still in the good category visually. The test for sending video data was carried out in two formats, including NTSC and PAL formats. In addition, this measurement was also carried out in LOS and Non-LOS conditions. The test results of the video image displayed on the headband monitor screen are presented in Table 3 and Table 4.

Table 3. Video image in LOS conditions

Distance (m)	Video in NTSC format	Video in PAL format
10		
20		
30		

Table 4. Video image in Non-LOS conditions

Distance (m)	Video in NTSC format	Video in PAL format
10		

Distance (m)	Video in NTSC format	Video in PAL format
20		
30		

C. Robotank Speed Testing

Robotank speed testing is done to determine the average speed with different PWM duty cycles. In this study, mathematical calculations are used to estimate the speed of the robot. The scenario of the robot speed test is carried out by setting the output PWM values that vary, including 100%, 80%, and 60% duty cycle, where two DC motors are given the same PWM value for forwarding movement. The test results in this scenario can be seen in Table 5.

Table 5. Robotank speed test results

Distance (m)	Time (s)			Speed (m/s)		
	Duty Cycle 100%	**Duty Cycle 80%**	**Duty Cycle 60%**	**Duty Cycle 100%**	**Duty Cycle 80%**	**Duty Cycle 60%**
1	1.23	1.49	1.62	0.81	0.67	0.61
1	1.17	1.42	1.6	0.85	0.7	0.62
1	1.27	1.43	1.68	0.78	0.69	0.59
2	2.33	2.53	2.79	0.85	0.79	0.71
2	2.2	2.46	2.66	0.9	0.81	0.75
2	2.39	2.47	1.78	0.83	0.8	0.71
3	3.4	3.63	3.89	0.88	0.82	0.77
3	3.39	3.6	3.93	0.88	0.83	0.76
3	3.48	3.62	4.05	0.86	0.82	0.74
		Ave.		**0.84**	**0.77**	**0.69**

D. Robotank Working Duration Testing

This test is intended to determine the duration of robotank work based on battery life. The battery used in this test is a Li-polymer battery with a voltage of 7.4 volts and a current of 1.5 A. The current consumption needs of robotank can be seen in Table 6.

Table 6. Current consumption in Robotank

Device	Current requirements
DC Motor	0.66 A
3DR Receiver	0.025 A
Video Transmitter	0.35 A
Total	1.035 A

To calculate the ideal battery life according to the current consumption, one can use the following (1).

$$Durability \;=\frac{battery\ Current}{Total\ current\ consumption} \qquad (1)$$

$$=\frac{1.5\ Ahours}{1.035\ A}$$

$$=\ 1.44\ hours$$

The test when the robot is running is carried out using a fully charged battery. This experiment was carried out 4 times, and the robot is conditioned to keep moving on an oval track. Table 7 shows the results of the battery endurance test on the robotank.

Table 7. Battery life test results

Experiment	Time	Ann.
1	01.00 PM	Start
	01.30 PM	The robot is still running fast
	02.00 PM	The robot is still running fast
	02.30 PM	The robot starts to slow down
	02.35 PM	Robot stops moving
2	10.00 AM	Start
	10.30 AM	The robot is still running fast
	11.00 AM	The robot is still running fast
	11.27 AM	The robot starts to slow down
	11.30 AM	Robot stops moving
3	03.00 PM	Start
	03.30 PM	The robot is still running fast
	04.00 PM	The robot is still running fast
	04.59 PM	The robot starts to slow down
	04.05 PM	Robot stops moving
4	12.00 PM	Start
	12.30 PM	The robot is still running fast
	01.00 PM	The robot is still running fast
	01.38 PM	The robot starts to slow down
	01.41 PM	Robot stops moving

IV. DISCUSSION

The results of the control distance test, both LOS and non-LOS, as shown in Table 1 and Table 2, it is known that the maximum control distance for both LOS and non-LOS robots is 20 meters and 16 meters, respectively. The presence of obstructions affects the transmission distance, where the control distance becomes shorter than before. Meanwhile, in testing the effect of transmission distance on video quality, it can be concluded that a transmission distance of 30 meters still provides excellent video quality, which is still visually acceptable. Meanwhile, in the Non-LOS scenario, the transmission distance of 30 meters still provides acceptable video image quality.

The average speed of the robot from a distance of 0 to 3 meters is 0.84 m/s for 100% PWM duty cycle, 0.77 m/s for 80% PWM duty cycle, and 0.69 m/s for duty cycle 60%. It can be concluded that the greater the PWM duty cycle given, the robotank will run faster and vice versa. If the PWM duty cycle given is small, the robotank will run slower. From this test, it is known that the maximum speed of the robotank is 0.84 m/s. In the actual condition when all work functions are activated, the maximum working duration of the robot is approximately 1 hour 52 minutes. The remaining voltage on the battery used is 5.90V, and in this state, the robot cannot respond to commands. The actual durability of the robot is slightly longer than the mathematical estimation of ideal conditions. This condition can be because, in turning conditions, only one DC motor is working. The actual test generates a longer working duration than the estimate given in the calculation based on current requirements. This condition is because the DC motor work in actual conditions is not used continuously.

V. CONCLUSION

In this study, a prototype mobile robot for space exploration has been successfully implemented. This robot is designed to resemble a tank and is then called a robotank. Robotank can be controlled remotely and is equipped with a video camera. Robotank can be controlled with a maximum distance of 20 meters. Furthermore, Robotank can monitor using the fat shark module with a maximum transmission distance of 30 meters. Robotank has compact dimensions and is relatively small with a size of 11.8 × 10.8 × 9.1 cm. Robotank can move with a maximum speed of 0.84 m/s in a 100% PWM duty cycle. The video is displayed on a screen installed on an LCD headband. Besides, Robotank can run for 1 hour 52 minutes. In the future, robotank is expected to be used for room exploration, which is dangerous and has limited space.

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REFERENCES

[1] M. O. Qureshi and R. S. Syed, "The impact of robotics on employment and motivation of employees in the service sector, with special reference to health care," Saf. Health Work, vol. 5, no. 4, pp. 198–202, 2014.

[2] I. Benaoumeur, A. F. Zoubir, and H. E. Amar Reda, "Remote control of mobile robot using the Virtual Reality," Int. J. Electr. Comput. Eng., vol. 5, no. 5, pp. 1062–1074, 2015.

[3] A. M. López et al., "Exploring the Seafloor with Underwater Robots," Comput. Vis. Veh. Technol., no. February, pp. 75–99, 2017.

[4] O. Alvear, N. R. Zema, E. Natalizio, and C. T. Calafate, "Using UAV-based systems to monitor air pollution in areas with poor accessibility," J. Adv. Transp., vol. 2017, pp. 1–14, 2017.

[5] M. Nagai, A. Witayangkurn, K. Honda, and R. Shibasaki, "UAV-based sensor web monitoring system," Int. J. Navig. Obs., vol. 2012, pp. 1–7, 2012.

[6] R. Diya and J. M. Jafferson, "Development of Autonomous Underwater Robot with minimum sensing devices," Int. J. Eng. Tech. Res., vol. 7, no. 4, pp. 41–43, 2017.

[7] R. Pérez-Alcocer, L. A. Torres-Méndez, E. Olguín-Díaz, and A. A. Maldonado-Ramírez, "Vision-Based Autonomous Underwater Vehicle Navigation in Poor Visibility Conditions Using a Model-Free Robust Control," J. Sensors, vol. 2016, pp. 1–16, 2016.

[8] Y. Ratnasari et al., "N3-AUV (Nusantara 3-Autonomous Underwater Vehicle): Design and implementation for underwater exploration," IOP Conf. Ser. Earth Environ. Sci., vol. 429, no. 1, pp. 1–7, 2020.

[9] P. J. B. Sánchez, M. Papaelias, and F. P. G. Márquez, "Autonomous underwater vehicles: Instrumentation and measurements," IEEE Instrum. Meas. Mag., vol. 23, no. 2, pp. 105–114, 2020.

[10] K. Yamamoto and T. Aoki, "Development of novel mobile robot with semicircular wheels," ROBOMECH J., vol. 7, no. 1, pp. 1–11, 2020.

[11] F. Rubio, F. Valero, and C. Llopis-Albert, "A review of mobile robots: Concepts, methods, theoretical framework, and applications," Int. J. Adv. Robot. Syst., vol. 16, no. 2, pp. 1–22, 2019.

[12] S. Böttcher, Principles of robot locomotion. 2006.

[13] P. Wieber et al., "Modeling and Control of Legged Robots," in Springer Handbook of Robotics, Springer International Publishing, 2020, pp. 1203–1234.

[14] T. B. Sheridan, "Human–Robot Interaction: Status and Challenges," Hum. Factors, vol. 58, no. 4, pp. 525–532, 2016, doi: 10.1177/0018720816644364.

[15] M. Ben-Ari and F. Mondada, "Elements of Robotics," in Elements of Robotics, 2017, pp. 1–308.