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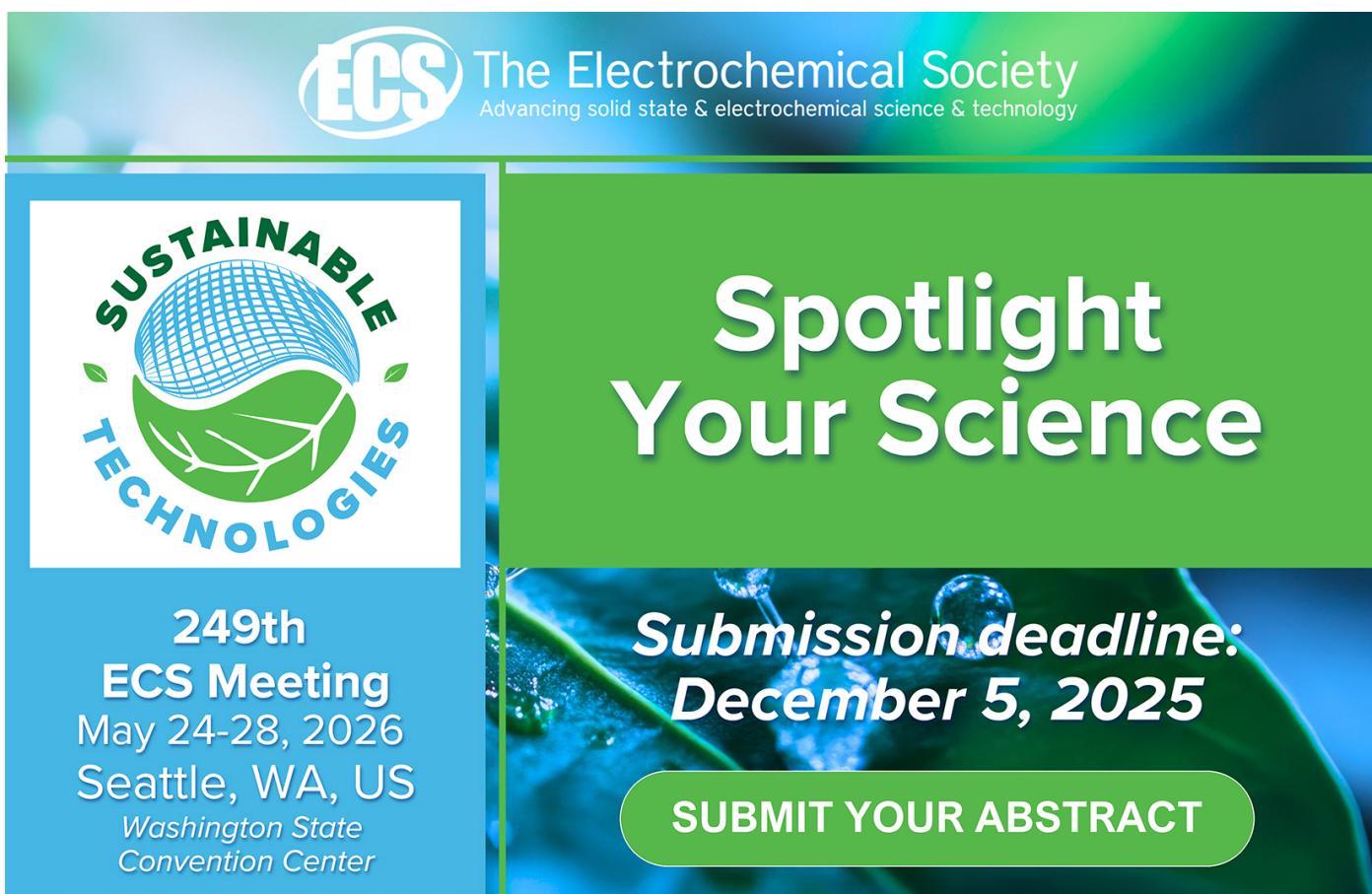
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Wireless Greenhouse Monitoring System Using Tricycle Mobile-Robot Based On Raspberry PI

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Abstract. The global population is projected to grow from around 7.3 billion (in 2017) to nearly 9.8 billion in 2050. In low-income countries, the population can double to 1.4 billion. Therefore, a 50 percent increase in food and other agricultural production will be needed from 2012 to the middle of the century. This increase has implications for agriculture and the food system to adapt significantly to becoming more productive and diversifying while overcoming climate change and unpredictable natural disasters. With integrated agricultural technology, agricultural productivity can also be increased even in limited land. Based on this, in this study, a wireless mobile-robot control system was developed which was designed to support a smart-greenhouse monitoring system using the Raspberry Pi. Mobile-robot made using the tricycle drive system. Mobile-robot is also equipped with 2 DOF manipulator arms to drive the monitoring camera mounted on the robot. Temperature and humidity sensors are also connected to the Raspberry Pi controller to be able to read environmental conditions in the green-house in real-time. Utilizing VNC remote desktop technology, the GUI application from Raspberry Pi can be accessed wirelessly using a network that is available on a green-house. The output of this research is a wireless control system on a mobile-robot for remote monitoring of greenhouse conditions.

1. Introduction

The global population is projected to grow from around 7.3 billion (in 2017) to nearly 9.8 billion in 2050 [1]. In low-income countries, the population can double to 1.4 billion. Therefore, a 50 percent increase in food and other agricultural production will be needed from 2012 to the middle of the century. This increase has implications for agriculture and the food system to adapt significantly to becoming more productive and diversifying while overcoming climate change and unpredictable natural disasters. Transfer of the function of agricultural land into residential land can also provide a negative impact on agricultural productivity. Based on data from the National Defense Agency, in Indonesia, there has been a conversion of agricultural land by 150 thousand hectares per year. Therefore, the development of integrated agricultural technology has become one of the main research focuses on the Department of Information Technology, State Polytechnic of Jember. With integrated agricultural technology, agricultural productivity can also be increased even in limited land.



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Several agricultural technology innovations were developed to overcome the problem of land limitations in increasing agricultural production, including hydroponic systems, potting systems, vertical plantations, etc. Besides, greenhouse technology can also be developed on limited land. The greenhouse also has advantages in dealing with climate change and weather [2]. In this study, a mobile robot was designed to work in a Green-house environment. Mobile-robots are equipped with manipulator arms that can be used to carry out several treatments on green house plants. Mobile-robot manipulator [3] [4] is designed to support the smart-green house system [5] [6], which was widely developed in this decade. The research was made by the road map of the Higher Education in the Department of Information Technology at the State Polytechnic of Jember in the development of precision farming systems, automation, control systems, and other applied systems that support integrated agricultural informatics. In this study, a teleoperation system was created to control the movement of mobile-robots [7] [8] wirelessly. The mobile-robot control system is wirelessly designed to support the Raspberry Pi-based smart-greenhouse monitoring system. Mobile-robot made using the tricycle drive system. A servo is mounted on the back of the robot as a regulator of the robot maneuver. Mobile-robot is also equipped with 2 DOF arm manipulator [9] to drive the monitoring camera mounted on the robot. Temperature and humidity sensors are connected to the Raspberry Pi controller to be able to read environmental conditions in the green-house in real-time. Utilizing VNC remote desktop technology, the GUI application from Raspberry Pi can be accessed wirelessly using an intranet network available on green-houses. The output of this research is a wireless control system on a mobile-robot for remote monitoring of greenhouse conditions.

2. Research Methods

This research method consists of several stages, such as literature review, data collection, parameter identification and data processing, application development, results and discussion, conclusions and recommendations.

2.1 Literature Review

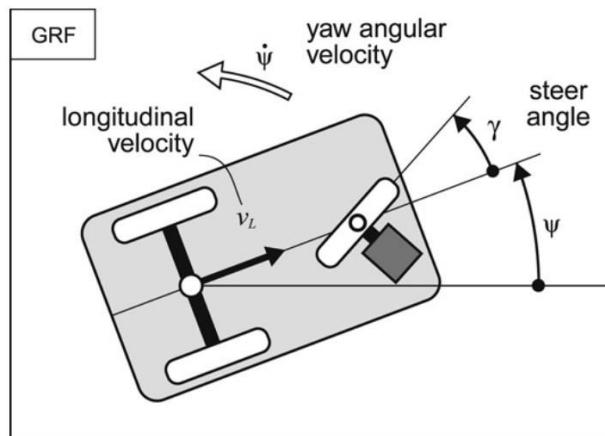
A literature review is carried out to collect information from several references related to the issues to be discussed. Theories related to research problem are used as a basis for processing data. At this stage, identification and problems formulation will be conducted which will be the objectives of the research. Problem formulation to be examined based on the background of the problem.

2.2 System Design

Mobile-robots are designed with a tricycle drive system [10][11]. 2 DC motors mounted on the front-wheel-drive system. One wheel that is coupled with a DC servo motor is used as mobile-robot steering. To be accessed wirelessly, this mobile-robot uses a Raspberry Pi 3 controller. Later, the Raspberry Pi controller is remote from the local WLAN network using the remote desktop VNC facility. Figure 1 is a mobile-robot design created in this study.

2.3 System Realization and Testing

In the next stage, the system is realized according to the design made. At this stage, various tests were also carried out such as the driving motor, steering wheel, camera access and sensor response to environmental conditions in the green-house. If the entire device works well, then a real test is performed in the greenhouse arena. Later, the mobile-robot will be controlled from a laboratory within 2 KM from the green-house area.

**Figure 1.** Robot design

2.4 Results and Discussion

The results of the system testing are then analyzed to determine the performance of mobile-robots in the field. Error-values, data transmission delays, or maneuver instability are used as references to improve robot performance.

2.5 Conclusions And Recommendations

This stage is the final stage of the research that draws conclusions from the results of the analysis of the discussion and provides suggestions for further research. This stage reviews the implementation of related technology/research, this is carried out to ensure that the research has a novelty contribution to the research fields,

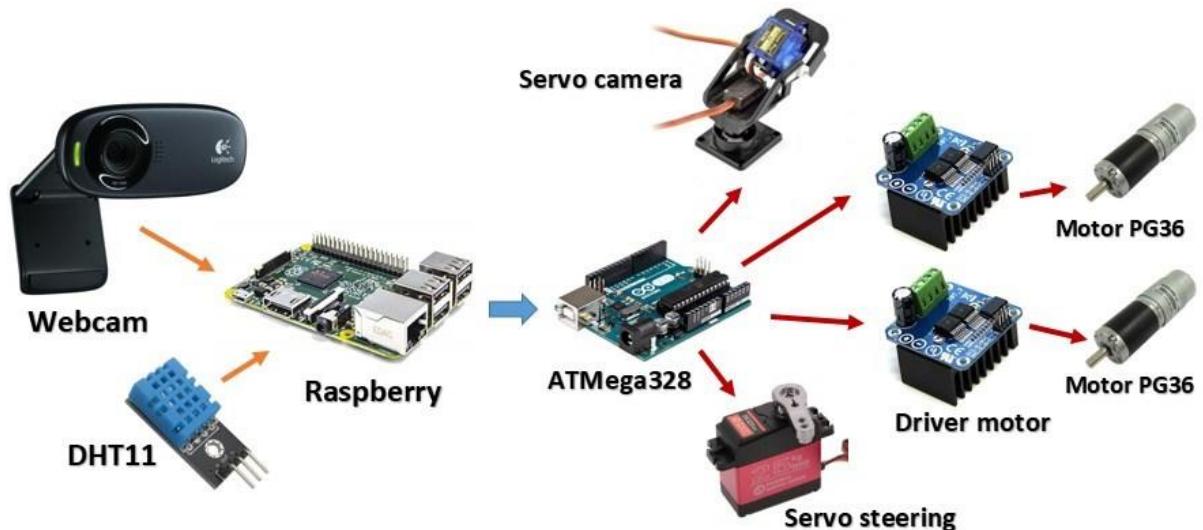
**Figure 2.** Block diagram system



Figure 3. Mobile-robot hardware

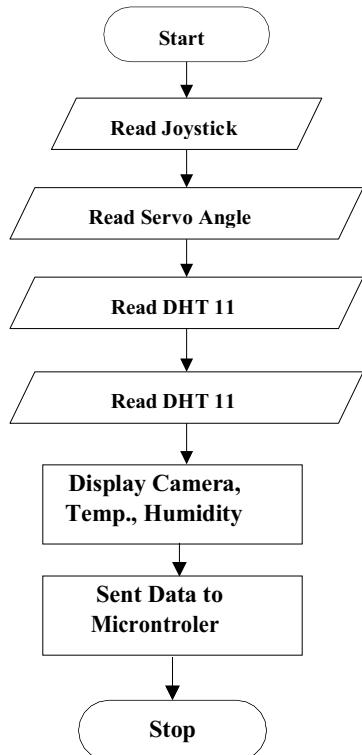


Figure 4. Flowchart system

3 Result and Discussion

3.1 Realization of hardware.

As per the design in figure 1, the mobile robot is made with a tricycle drive system. The front-wheel-drive of the robot uses a DC motor type PG36. This motor has 18kg.cm of torque and a rotational speed of 8000rpm 24volt DC. On the rear wheels, a DS3225 type servo motor is used with a torque of 24.5kg.cm and a rotational speed of 0.15sec / 60 degrees at a working voltage of 5 Volt DC. At the top of the robot, a 2DOF arm is used to adjust the camera's working angle. A camera with 5M Pixel resolution is used for monitoring Greenhouse conditions in real-time. All actuators are connected to the ATMega328 microcontroller.

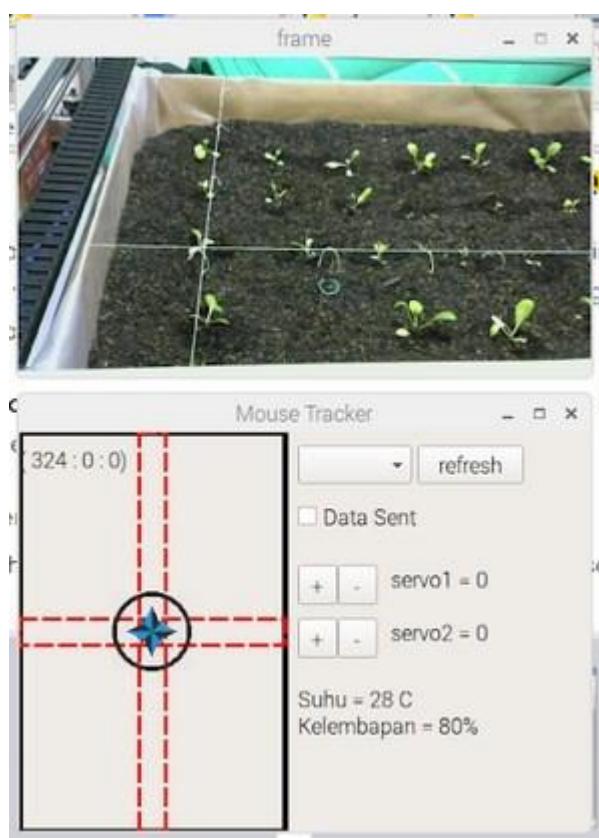


Figure 5. GUI

The BTS7960 motor driver is used to control the direction and rotational speed of the PG36 DC motor. PG36 motors are coupled with 15cm diameter wheels. It is intended that the robot can maneuver properly in uneven areas. The rotating speed of the motor is controlled by utilizing the PWM facility on the microcontroller. The ATMega328 microcontroller is connected to the main controller (Raspberry Pi) via USB-serial communication with a baud rate of 57600. Raspberry Pi will send data on the direction & rotational speed of the PG36 motor and the working angle of the servo steering. A DHT11 sensor is also connected to the GPIO raspberry pi pin to measure the temperature and humidity values in the greenhouse. Figure 2 is a block diagram of the system used in this study. Figure 3 is the result of the realization of the mobile-robot. The results of the system testing are then

analyzed to determine the performance of mobile-robots in the field. Error-values, data transmission delays, or maneuver instability are used as references to improve robot performance.

3.2 Making application

GUI applications are made by utilizing the PyQt GUI feature in Python programming. In the GUI, there is 1 joystick control by utilizing the image feature. This joystick is used to adjust: the direction & speed of the driving motor, and the working angle of the servo steering. There are also 2 pieces of scroll bars to adjust the working angle of the servo on the camera. Besides, there are also component labels to display data on the temperature and humidity of the Greenhouse environment. For mobile-robot movement settings, users simply adjust the position of the joystick by dragging and dropping using the mouse. The speed and direction of motor rotational values are obtained by converting the pixel position in the image using equation 1. Servo steering work angle is obtained by converting the pixel position in the image using equations 1 & 2. The actuator value setting data on the robot is sent every 300mS to the ATMega328 microcontroller. Figure 4 is a programming flowchart on the microcontroller. Figure 5 is a GUI display created for controlling mobile-robots wirelessly.

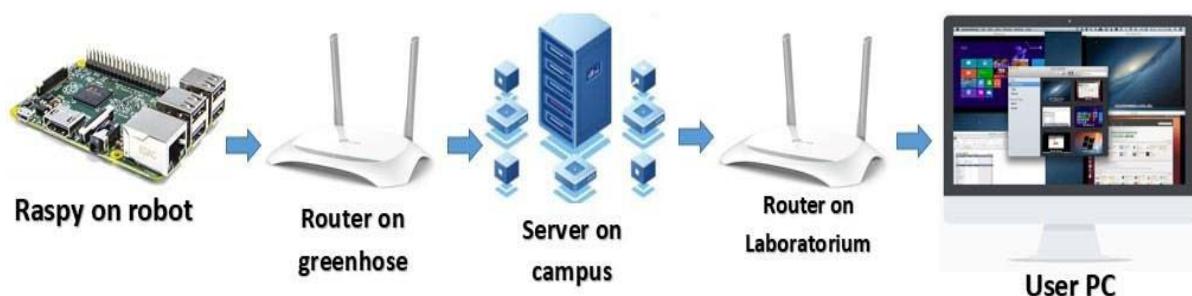


Figure 6. Tampilan GUI

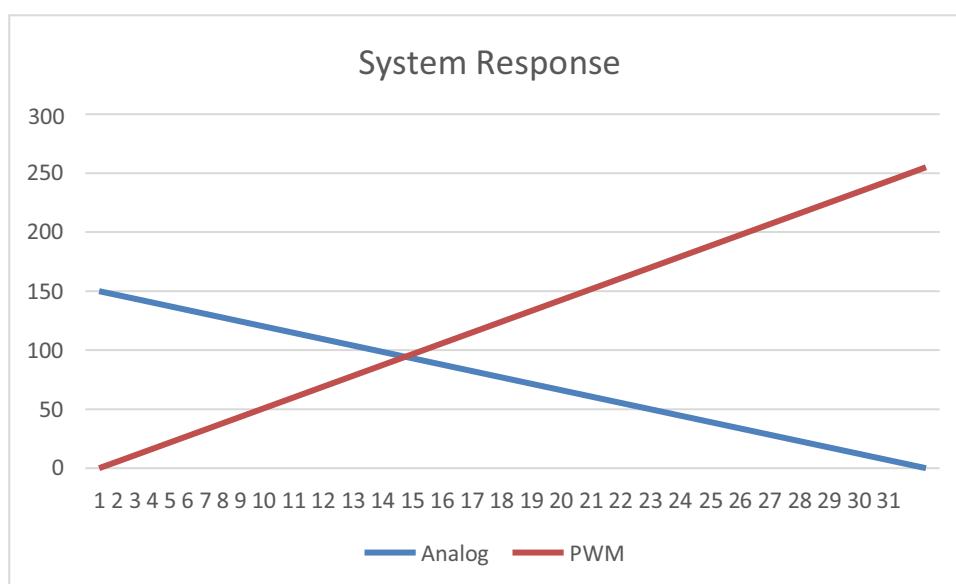


Figure 7. System response

3.3 Systems Testing

To control mobile-robots wirelessly, Raspberry Pi must be connected to an access point that is in a green-house. This network is connected locally with the network in the laboratory. Furthermore, the user's computer only needs to access the Raspberry Pi through the VNC Remote Desktop application. The greenhouse robot teleoperation system is illustrated in Figure 6. Figure 7 is the data of the teleoperation system test results on mobile-robots.

4 Conclusion

Based on the results of research that have been done, successfully created a mobile-robot with a tricycle driver that can be controlled wirelessly from a distance. The standard wireless data transmission speed of the Sensors Network is 5.5 Mbps. By utilizing a webcam camera connected to a raspberry, users can find out the condition of the greenhouse environment in real-time. Robot drive systems with large diameter wheels also allow the robot to maneuver in uneven areas.

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