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Design and Function Evaluation of Line Follower Plant Sprayer Robot

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ABSTRACT– Agriculture tools necessary for increasing food security in Indonesia. An automatic spraying for plant became one of the tool that help in pot plant maintenance. This study was developing a prototype of automatic line follower robot for spraying plant. Designing a new construction and adding a line follower sensor, this robot could move between plant pots with guidance of black line. Main chassis of this robot made from 3 mm aluminum plate with 50 cm length and 20 cm width. Control of this robot using Arduino Uno as microcontroller that could control the movement of the robot and also could control movement of nozzle and flow rate. Performance testing of this robot held inside the room with concrete floor and placed on the white fabric with black line as a guidance and sign to stop and spray. As the result, average linier speed for this robot was 0,7 m/s and flow rate for spraying was 8,9 ml/s with 89,5% accuracy.

Introduction

The development of robotic technology in agriculture has a very large effect on the maintenance and development of efficient food production. Currently, food production faces considerable challenges in terms of economy, production efficiency, environmental problems, and labor problems [1]. To answer these challenges, new innovations in agricultural machines are needed, such as research [2], the application of automation, and the application of robotic technology that can really increase production efficiency [3] or harvest efficiency [4].

In facing these challenges, research and development of agricultural automation and robotic technology applications in Indonesia has begun to be carried out. Some of these studies, namely sprayer machines with variable doses [5], sprayer machines for fertilizer application for sugarcane [6], robotic rice rat repellent [7], and four-wheel automatic tractors [8]. However, the application of agricultural robotic technology in Indonesian agricultural land has not been widely used.

Plant care activities are carried out intensively and periodically so that plants can grow and produce well. One of the plant care activities is plant spraying. Spraying of plants is carried out for various uses, including watering, fertilizing, pests and diseases. Plant spraying machine (sprayer) serves to change the liquid or solution into fine granules.

In this research, a prototype of a plant spraying robot was developed. The developed robot is expected to be able to walk on a concrete floor between rows of potted plants. To be able to walk in accordance with the desired path, the path to be traversed and the position of the plant pot is marked with a black line.

Method

2.1 Materials

The tools and materials used in this study are divided according to the stages of the activities. Construction design and programming activities use a computer with the required programs/software installed. The construction design is carried out using the Autodesk Inventor program and in making the control program using the Arduino IDE microcontroller. Prototype construction using workshop equipment, including saws, welding, hammers, drills, and other workshop equipment. The prototype construction materials use aluminium plates, iron rods, acrylic, nozzles, electric pumps, plastic tanks, arduino uno, photodiodes, DC motors, servo motors, batteries, and relays.

2.2 Construction Design

The prototype of the plant spraying robot that has been developed consists of several main parts, such as frame, drive system, spraying system, and control system. The frame serves as a place to put all the components of the robot. The frame structure must be strong enough to support the weight of the robot equipment and makes it easy for the robot to maneuver between rows of plants. The drive system consists of a DC motor, tires, and arduino serves to move the robot from one position to another. The spray system consists of a nozzle, pump hose and water tank functions to drain liquid from the robot tank to the plants. The water spray system also consists of a servo motor and a DC motor that serves to direct the nozzle in a certain direction. While the control system section consisting of a microcontroller contained in the Arduino and other electrical components functions to control the drive system and the spray system. The construction design of the plant spraying robot prototype can be seen in Figure 1.

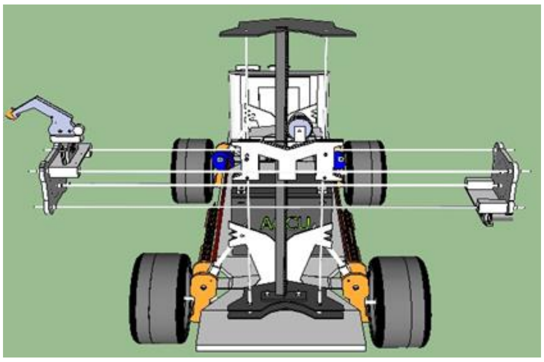

Figure 1. Front view of plant spraying robot construction design

The main frame of the robot is made of 3 mm thick aluminum plate with a length of 50 cm and a width of 20 cm. The aluminum material was chosen because it has a light weight and strong to support the entire load of robotic equipment. In addition to the main frame, the robot also has three vertical poles made of cylindrical iron with a diameter of 5 mm which function to support the vertical motion and horizontal motion of the nozzle. The nozzle mount allows the nozzle to move vertically up and down, move horizontally left and right, and rotate 1800. This is intended to make the spray range more flexible. Vertical movement uses a rack and pinion transmission system while horizontal movement uses a timing belt. Each horizontal and vertical movement is driven by a 5V DC motor while the nozzle rotation uses a servo motor.

The liquid storage tank is made of plastic with a capacity of 2.5 liters equipped with an electric pump. The pump power is 40 W with a DC voltage of 12 V and a flow capacity of 10 ml/s. The pump and tank are safe for chemical solutions, such as liquid fertilizers, pesticides, and herbicides.

In the driving part, the robot uses four rubber wheels with a diameter of 60 mm with each wheel connected to a 12 V DC motor. The rotation speed of each motor is 100 rpm with a maximum torque of 3.6 kg.cm. The selection of this driving method is expected to be able to move the robot and maneuver with a total load of 8 kg.

2.3 Control System Design

In general, the control system used in this study can be seen in Figure 2. The robot control center using the Arduino Uno microcontroller serves to receive and process input from sensors then make decisions about the movement of each actuator through motor drivers or relays based on the algorithm that has been implanted. The photodiode sensor used to detect a black line as a robot trajectory. The LCD screen is used to monitor the status of the command decisions made by the microcontroller.

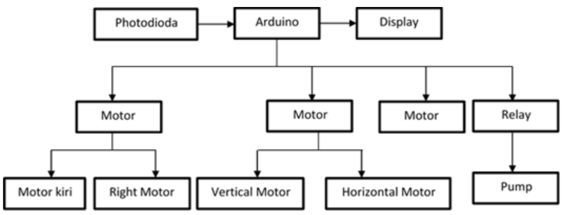

Figure 2. Control System Chart

The series of control algorithms for the plant spraying robot can be seen in Figure 2. The robot control algorithm starts from pressing the on-off switch of the robot in the "on" position manually. Then four photodiode sensors placed on the front of the robot read the black line of the robot's trajectory and the position marker of the plant pot.

2.4 Control Algorithm

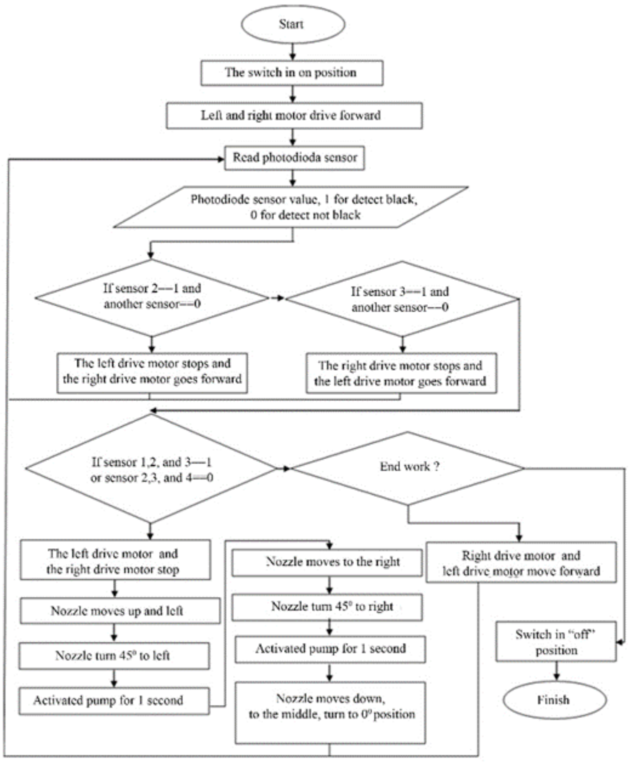

Figure 3. Control Algorithm Chart

Four photodiode sensors are placed on the front of the robot in a row from left to right of photodiode sensors 1, 2, 3, and 4. Photodiode 1 sensor is on the far left and photodiode 4 is on the far right. The initial vertical position of the nozzle is in the lowest position and horizontally is in the middle position with a nozzle direction angle of 00 or in a straight forward position. If photodiode sensor 2 detects black and sensors 1, 3, and 4 detect non-black color, then the robot's position tends to point to the right so the front and rear left wheel drive motors are stopped. On the other hand, if photodiode 3 detects black, and sensors 1, 2, and 4 detect non-black colors, the robot's position tends to point to the left so that the front and rear right wheel drive motors are stopped. If photodiode sensors 1, 2, and 3, or photodiode sensors 2, 3, and 4 detect black, then the robot is in the spraying position. In the spraying position, the robot stops moving forward, the vertical nozzle motor moves to the topmost position, the horizontal nozzle motor moves to the leftmost position then the nozzle rotates at 450 to the left and sprays for 1 second then stops, then the nozzle moves to the rightmost position then the nozzle rotates at 450 to the right and sprays for 1 second then stops, then the nozzle moves to the initial position again and the robot moves forward again. Meanwhile, if the four photodiode sensors detect a non-black color, the robot will move forward with the left and right wheel drive motors rotating forward. After the entire path has been passed, the robot's task is complete and the robot's on-off switch is pressed in the "off" position manually.

Result and Discussion

The prototype of the plant spraying line follower robot has been designed specifically for use on flat platforms. The robot is able to maneuver between rows of potted plants. The plant sprayer robot can be seen in Figure 4. Dimension of the robot is 500 mm x 200 mm x 400 mm and the total mass of the robot is 8 kg with a tank capacity of 2.5 liters. The testing result the average linear speed that can be taken by the robot with a maximum load of 0.07 m/s.

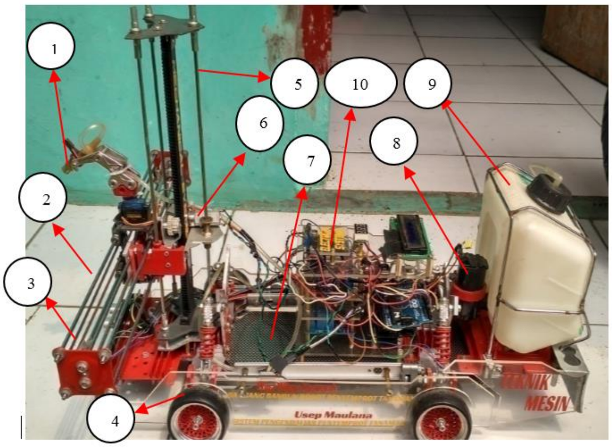

Figure 4. Plant sprayer robot

1. Nozzle
2. Horizontal Slide Bar
3. Horizontal Motor Drive
4. Tire
5. Vertikal Slide Bar
6. Vertical Motor Drive
7. Frame
8. Pump
9. Water Tank
10. Control System

The performance evaluation of the robot is carried out outdoors with a concrete foundation with a white base and a black line as a marker. There are two types of markers used, trajectory markers and stop markers for spraying, as shown in Figure 5. The trajectory markers shape of an unbroken long line and have a turning trajectory such as the letter U or a semi-circular trajectory. While the stop sign for spraying has a short straight line shape. A 240 ml plastic cup was used as a plant pot simulation. The distance between pot markers in one row is 50 cm, while the distance between rows of pots is 40 cm. The glass functions as a pot andd placed near the stop marking line for spraying.

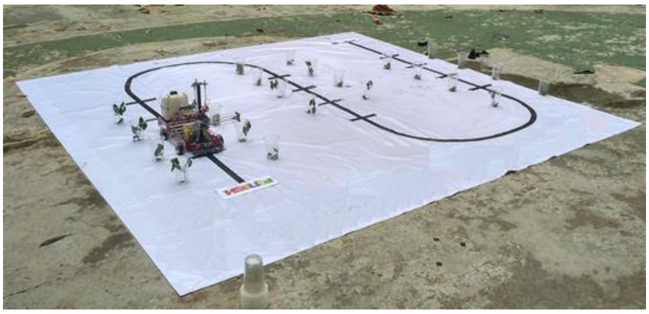

Figure 5. Performance test of plant spraying robot

Based on the results of performance evaluation, the average volume of the glass filled with water is 8.95 ml with a 100% success rate. A 100% success rate means that the robot is always successful in detecting the stop position marker and spraying. From the volume uniformity of water filled in the glass has an accuracy of 89.5%. The accuracy value indicates that not all of the water sprayed enters the glass. In every 100 ml of water that has sprayed, there will be 10.5 ml of water was spilled and not accommodated in the glass. The distribution of spraying volume can be seen in Figure 6.

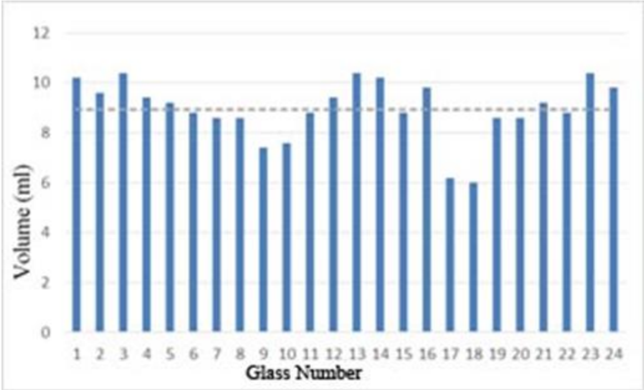

Figure 6. Volume distribution of spray water in the glass

The position of the glasses is in the first row start from number 1, 2, 3, 4, 5, 6, 7, and 8, where the glasses with odd numbers are on the left of the robot and the glasses with even numbers are on the right of the robot. Then turn back to follow the semi-circular path entered in the second row. The positions of the glasses in the second row are also placed sequentially as in the first row, namely glasses 9, 10, 11, 12, 13, 14, 15, and 16, where the odd number glasses are on the left of the robot and so on until the third row. Figure 5 showed that glasses 9, 10, 17, and 18 have a fairly large volume below the average when compared to other glasses. It is because the position of the glasses after the turning trajectory. At that time the position of the robot was not yet in a perfectly straight position parallel to a straight line. So when the robot sprayed water, the volume of water that spilled was quite a lot. The results of this study were compared with the the same study of implementation a line follower robot for automatic plant watering [9]. This study reported the success of the robot in detecting the pot marker so that the robot stops and sprays water was 85% which means that at a certain time the robot fails to spray water according to the given sign. However, in this study, the success of spraying with the volume of liquid that managed to enter the pot/reservoir was not obtained.

Conclusion

In this study, a prototype of a line-following automatic plant sprayer robot has been successfully developed which is able to follow the trajectory marked with a black line and 100% success to detect the spraying position marker. The average forward speed of the robot is 0.07 m/s and the average spraying discharge is 8.9 ml/s. The performance evaluation shows the uniformity of the amount of water sprayed has an accuracy of 89.5%.

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