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The Pesticide Spraying Robot Moving in A Greenhouse with A Line-Trace

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***Abstract*—Excessive pesticide spraying is a serious problem and hard labor that causes farmers' health hazards such as poisoning. In particular, since the greenhouse is sealed, it is easier for them to inhale pesticides when spraying pesticides, therefore automation using robots is required. This study has developed a robot that sprays pesticides autonomously in a greenhouse. To spray pesticides only on the crops of the ridges, the developed pesticide spraying robot can spray pesticides while line-tracing between the ridges in a narrow greenhouse by analyzing the image of the packing plastic tape installed on the ridges. In addition, since the robot developed in this study runs autonomously between the ridges by a simple line-trace, it can be introduced without having the widen the space between the ridges, which makes it possible to prevent a decrease in the yield of crops. Furthermore, the construction costs can also be reduced. Moreover, by using a microcomputer, it is possible to check the temperature, humidity, and illuminance data in the house on the web screen in real-time from an external farmer's PC at a web server and prevent death in the greenhouse. Therefore, the developed robot will take a picture of the state of pesticide spraying with a webcam so that it can be confirmed on the server in real-time, and it can be expected to function as a patrol robot.**

Keywords—Pesticide spraying robot, greenhouse, line-trace,

I. INTRODUCTION

Farmers spray pesticides regularly because consumers do not choose vegetables and fruits that are bruised by disease or eaten by pests. However, this excessive spraying of pesticides is also a serious problem that causes health hazards such as poisoning to farmers, and it is hard work [1]. In particular, since the greenhouse is sealed, it is easier for farmers to inhale pesticides when spraying pesticides, so automation by using robots is required [2-6]. To operate a robot that sprays pesticides while moving autonomously to crops, the space between the ridges is widened to create a trail. For that purpose, there are cases where a part of the ridge is removed, gravel is laid, concrete is poured and hardened on it, and a new rail that will be followed by the robot follows is installed on it [7]. However, since these constructions require cost and construction period, they are not widely used at present.

The authors have proposed the automation of pesticide application using robots against the background of severe agricultural population decline and aging in Japan [8,9]. In this study, we have developed a pesticide spraying robot that uses a requiring trail autonomous line-tracing method in the greenhouse without creating a track for the robot to move between the ridges in the greenhouse. This robot recognizes crops by image analysis with a CCD camera and sprays pesticides autonomously. In addition, it also has a system that allows farmers to know the temperature, humidity, and illuminance in the greenhouse from a mobile device at home.

II. ROBOT SPECIFICATIONS AND RUNNING SYSTEM BY LINE-TRACE

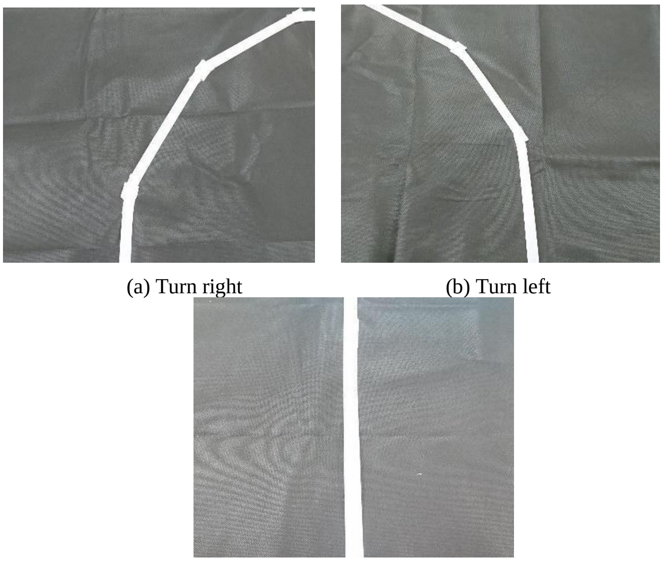
As shown in Fig. 1, the width of the robot is suppressed to 43 cm for the robot to run between the ridges of 1 m or less, and NI's myRIO is used for control of movement by line-trace. The CCD camera is attached to myRIO and controlled by LabVIEW [3]. The robot is equipped with two sprayers to spray pesticides on the crops on both sides of the robot, and it is possible to spray pesticides sufficiently on the ridges with a length of 120 m. Since the spray of the pesticide is only on the crop, the distance to the objects on both sides of the robot and the image are analyzed using an ultrasonic distance sensor and a CCD camera, and the pesticide is sprayed only when a crop is recognized.

Fig.1 pesticide spraying robots

Fig. 2 shows an example of a between the ridges (furrows) on which the robot runs. The general length of the ridges is 40m, the width is 1m, and the distance of furrows is 0.75m. Plastic tires with a diameter of 140 mm and a width of 50 mm were used for the robot. A rod-shaped rubber with a diameter of 4 mm was fixed to the tire at intervals of 20 mm to run on furrows of rough terrain. To spray efficiently while running accurately between the ridges, polypropylene string is installed between the ridges, and by analyzing the image of the string, the robot runs on narrow furrows [10].

Fig. 2 Example of furrows on which the robot runs

PID control was attempted for controlling the amount of motor drive, but in actual farmland, it was sometimes not possible to turn completely on a curved line. Therefore, as shown in Fig. 3, we subdivided the value of the straight edge (Angle) into seven patterns: one straight line and three patterns that turn to the left and right, respectively, to correspond to the curve. By separating the patterns, it became easier to control the drive amount (Power) of the motor.



(a) Turn right (b) Turn left

(c) Go straight

Fig. 3 Line image pattern

Fig. 4 shows the image analysis program for line-trace. In Vision Acquisition2, the setting is made so that the CCD camera acquires images continuously. The obtained image is sent to Vision Assistant, binarized, and image analysis is performed using straight edges to output the slope of the line as seen by the robot as a value (Angle) [11,12]. Also, at the same time as image processing, the image before binarization is output to ImageOut2 to check the operation. The drive amount of the DC motor is controlled by the value (Angle) measured by image analysis with Vision Assistant. As shown in Fig. 4, the directions in which the robot moves are divided into straight-line, left, and right, depending on whether the value of the straight-line edge (Angle) is close to 0, true or false.

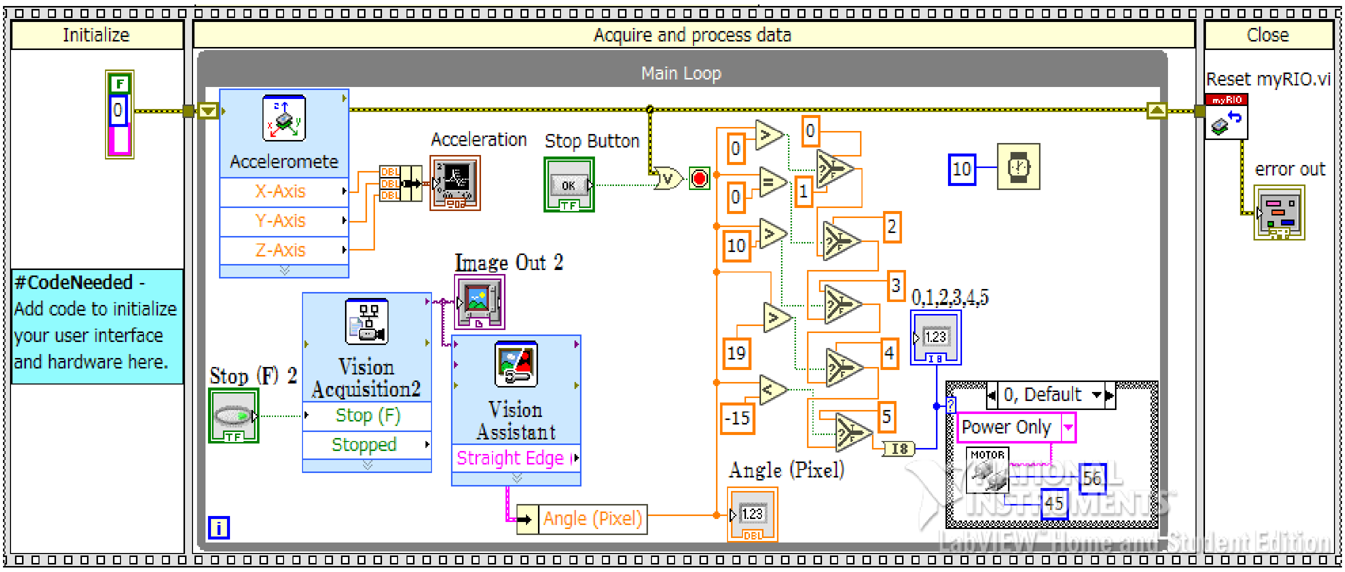


Fig.4 Line trace image analysis program

We decided the mounting position of the line-trace CCD camera, increased the straight edge pattern, and selected a value (Angle) that makes it easier to control the drive amount (Power) of the motor. This method allows the robot to spray pesticides while tracing the line between the ridges in a narrow greenhouse.

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III. REMOTE ENVIRONMENTAL CONFIRMATION IN THE HOUSE

There is a demand for labor-saving such as reducing the frequency of agricultural workers managing the condition of crops in the greenhouse in the early morning or under the scorching sun. Therefore, using the M5Stack microcomputer, we made it possible to check the temperature, humidity, and illuminance data in the house on the web screen in real-time from an external PC such as the farmer's home through a web server. The Si7021 temperature-humidity sensor and the S9705 phototransistor are mounted on the pesticide spraying robot, and the environmental information of the greenhouse can be checked in real-time as shown in Fig. 5.

The temperature/humidity/illuminance graph is drawn by the CSV file of Excel (see Fig. 6). Since the notified information can be confirmed on the PC at home, the farmer can judge the time zone for starting the farming work and the necessity of the work without going to the greenhouse.

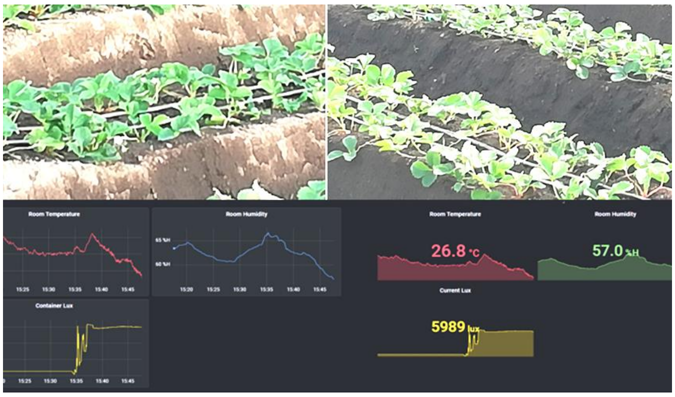


Fig. 5 Environmental information of Greenhouse

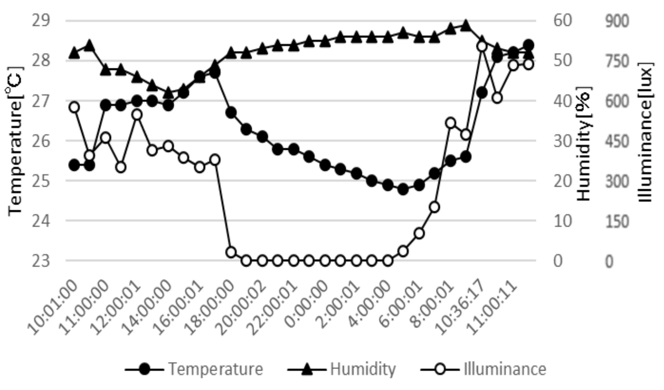


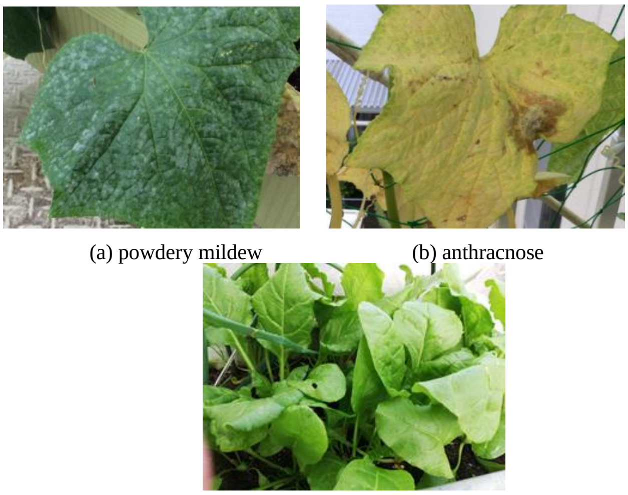
Fig. 6 Transition display of environmental information recorded on SD card

IV. DISCUSSION

The pesticide spraying robots have been developed for labor-saving of farmers [2-6], but many of these robots need to first reduce part of the ridge, then install gravel, and finally, pour and harden the concrete. It is necessary to install the rails that the robot runs. Not only are these constructions more expensive, but also the area of the ridges is reduced, occurring the new problem of decreased yields. Since the robot that developed in this study autonomously runs between the ridges by a simple line-trace, it can be introduced without widening the space between the ridges, and it is possible to prevent the crops in the yield of crops. In addition, the cost to install the rails can be reduced, and the number of farmers who use pesticide spraying robots will increase, which can be expected to make up for the labor-saving of farmers.

Some conventional pesticide spraying robots supply pesticides from an installed tank using a hose. However, it is difficult to supply pesticides by a hose in the greenhouse, and the pesticide supply hose may damage the crops. Therefore, the problem was solved by equipping two commercially available sprayers (maximum liquid volume 7ℓ) with pesticide tanks and spraying while moving 120 m or more.

In the summer, some farmers die from heatstroke in the greenhouse, which is a serious problem, and robots that move autonomously in the greenhouse have been developed [13-15]. In this research, we have realized that the temperature, humidity, and illuminance data in the house can be confirmed on the web screen in real-time on an external PC such as the farmer's home through a web server using a microcomputer. Therefore, farmers can also prevent death themselves in the greenhouse by using this system.



(a) powdery mildew (b) anthracnose

(c) dense spinach

Fig. 7 State of crops sent from robots in the greenhouse

Furthermore, the state of spraying is shown by a web camera. It is also possible to take a picture with the camera and check it on the server in real-time, and it can be expected to function as a patrol robot. As shown in Fig. 7, it is also possible to check the condition of crops sent from a robot moving in the greenhouse in real-time at home. By comparing the saved image data, farmers can always check the detection of disease-infected crops and how they grow densely and become difficult to grow, which is very useful for producing high-quality crops and determining the shipping time.

V. CONCLUSION

Excessive spraying of pesticides is also a serious problem that endangers farmer's health such as poisoning farmers and giving them harsh labor. Especially in a closed greenhouse, it is easy for farmers to inhale pesticides, so automation using robots is required. In this study, we developed a robot that sprays pesticides autonomously in a greenhouse and obtained the following conclusions.

1) To spray pesticides only on the ridged crops, the robot uses a distance measuring sensor and a CCD camera to analyze the distances and images to the objects on both sides and sprays the pesticides only when a crop is recognized.
2) By image analysis of the packing plastic tape installed on the ridges, it is possible for the robot to spray pesticides while line tracing between the ridges in the narrow greenhouse.
3) The robot developed in this study runs autonomously between the ridges by a simple line trace, so it can be introduced without widening the space between the ridges, and it is possible to prevent a decrease in crop yield. In addition, the cost of construction can be reduced.
4) Using a microcomputer, it is possible to check the temperature, humidity, and illuminance data in the house on the web screen in real-time on a farmer's PC through a web server. Therefore, farmers can also prevent death themselves in the greenhouse by using this system.
5) The developed robot can use a webcam to take a photo of the state of pesticide spraying with a webcam so that it can be confirmed on the server in real-time, and it can be expected to function as a patrol robot.

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