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Development of a seed-planter wheeled robot prototype

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Abstract. Planting seeds may be trivial and can be done manually. However, on a large scale, it will inevitably become time-consuming and labor intensive. The use of robot can be an alternative solution to improve the efficiency of this agricultural-related work so that farmers can focus more on the decision making perspective rather than the labor-intensive works. This study aims to develop a prototype of a task-oriented seed-planter robot that can be used to assist farmers. The robot has three wheels: two motorized wheels and one free-wheel for its stability. It is equipped and programmed with line follower sensors and algorithm to simplify its navigation procedure, by assuming that the field is already marked before plantation process. The main contribution of this study is the design of the actuators of the robot prototype which enables the robot prototype to dig a hole, plant the seed and then close the hole again.

1. Introduction

The rapid development of microcontroller technology has enabled robots to be more widely used in almost all aspects of human life, even in social matters [1]–[3]. Robots are designed to facilitate humans in various problems, such as medical problems [4], transportation and logistical problems [5], exploration and mapping problems [6], monitoring problems [7], and agricultural problems [8]. In agriculture, one of the tasks that can be done by robots is to plant seeds. Planting seeds is an easy thing and can be done manually, but when this job should be conducted on a large scale, it will inevitably become time-consuming and labor intensive. Several studies have been done to overcome similar problems in agriculture, proposing task-oriented robots in the form of autonomous tractors [9] [10]. The study in [9] proposed a robot farming system using multiple robot tractors. However, the study focuses on a system that regulates multi-robots (tractors) which are equipped with various sensors. In [10], a semi-autonomous robot tractor is proposed, where the robot is manually controlled by the farmer to dig a hole in certain spots. During the same time, the farmer can do other tasks such as planting seeds or fertilizing the plants.

In Indonesia, another serious problem in agriculture is aging farmers. One of the reasons behind the low interest of young generations in the agricultural field is the lack of technological aspects (not challenging). This study aims to focus on the design and development of a seed planter wheeled robot prototype that is interesting for younger generations, and can be scalable for real implementation in tractors, greenhouses, etc. Here, wheeled robot is chosen over legged robot because many-legged robot as in [11] may be too complex to be operated when the main focus of this study is to design the actuators of the robot with these specific tasks: dig a hole on the ground, drop the seed to the hole, and then close the hole again.



In this study, the wheeled mobile robot is developed using a simple line following algorithm for navigation and movement. The robots are equipped with sensors to track the line and detect the location to perform its main task: planting seeds. The seeds are stored in a container at the top of the robot before being dropped through a pipe. To dig a hole and close it again, this robot is equipped with an arm that can function as a drill as well as a scope. Experimental results indicate that the robot has successfully discovered the tasks and achieved its goals.

This paper is divided into five sections. Section 2 explains the design of the seed-planter wheeled robot prototype, which is the main contribution of this paper. Then, the developed robot is described in section 3. The experimental setup, results and analysis are explained in section 4. Then, this paper concludes with a summary of the result in section 5.

2. Design of a Seed-Planter Wheeled Robot Prototype

2.1. Materials

The materials for this robot prototype are as follows:

- Line tracking sensor BFD-1000
- Two motor drivers
- Three servos
- Three DC motors
- Three batteries (Li-ion 18650, 4 volts)
- Two acrylic chassis
- Wooden stick
- Glue
- Arduino Uno microcontroller

2.2. Robot Functionality Requirement

In this study, we define that the robot prototype should be able to perform these specific tasks:

- The robot can move along the line
- The robot can stop when it detects a “+” line
- The robot can dig a hole
- The robot can drop the seed through a pipe to the hole
- The robot can close the hole again

2.3. Physical Design

The physical design of the seed-planter wheeled robot prototype is shown in Figure 1. Figure 1 (a) shows the physical dimensions of the designed robot (bottom view). The robot has three wheels: two motorized wheels on the front and one free-wheel for stabilization on the back. This robot is a line-follower robot, so it must be able to detect a black line using a line tracking sensor BFD-1000 that is installed on the bottom-front of the robot. The line tracking sensor is equipped with five color sensors, namely outer-left sensor, inner-left sensor, center sensor, inner-right sensor, and outer-right sensor.

Figure 1 (b) shows the arm and the seed container. The arm is designed to facing out from the left side of the robot, which means that the robot prototype can only plant the seeds on its left side. The arm is specifically used for digging and closing the hole. It is built from a wooden stick and has two servos and one DC motor. One servo is used for arm movement (up and down) and the other servo is used to switch its end-effector function into either a drill or a scope. The DC motor is utilized to twist the drill and the scope so that the drill can dig a hole and the scope can close the hole again. The seed container of this robot is a funnel-shaped and equipped with one servo to open and close the bottom tip of the funnel so that a seed can be dropped and will slide through the pipe.

The designed robot consists of two layers: the breadboard, microcontroller, and sensor are placed in the first layer (Figure 1 (c)), while the arm, seed container, and motor driver are placed in the second

layer (Figure 1 (d)). In order to move, this robot should control its two wheels on the left-front and right-front side of the robot, where each wheel is motorized by a DC motor and supported by a motor driver.

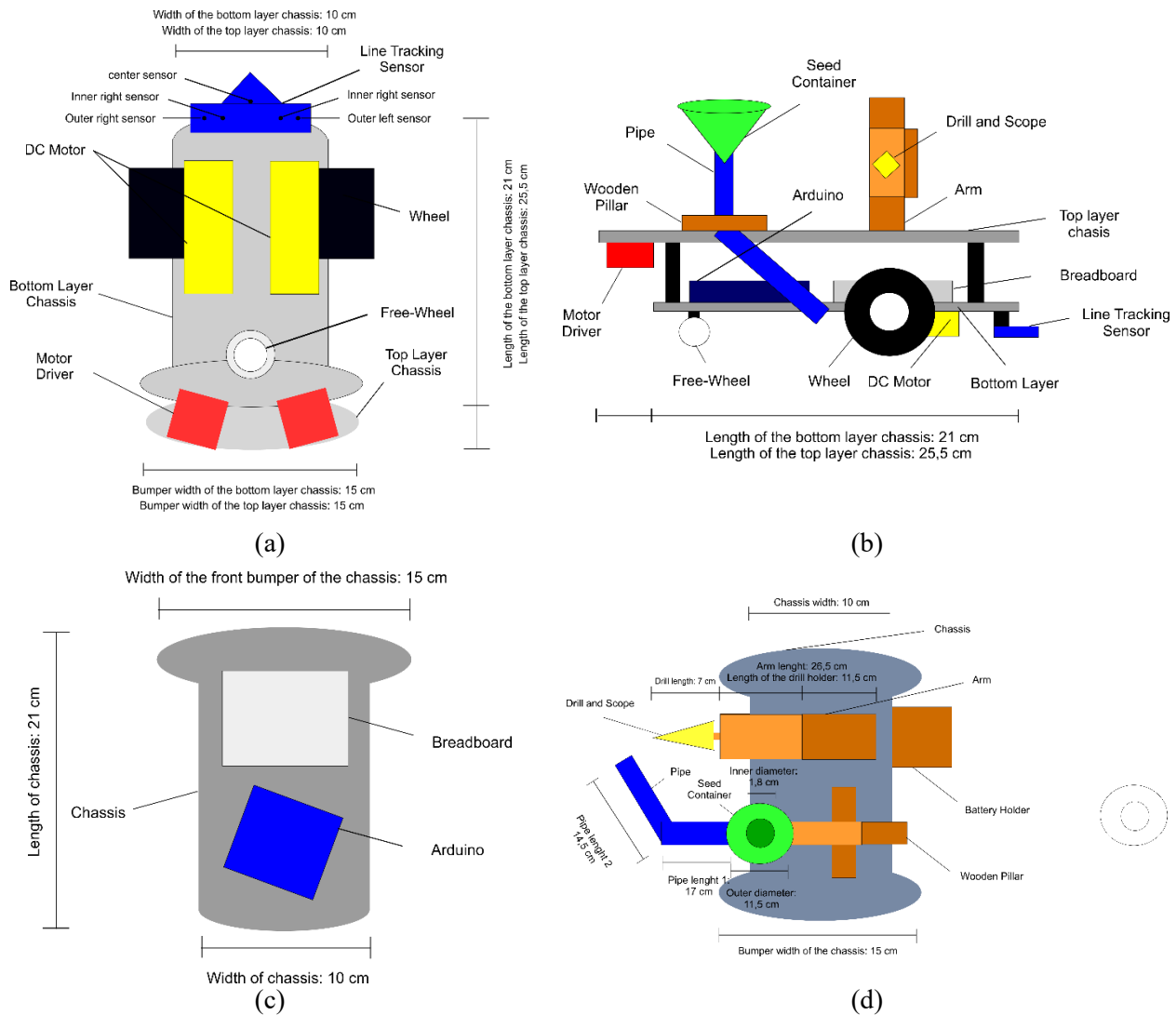


Figure 1. Physical Design of the Seed-Planter Wheeled Robot; (a) bottom view, (b) side view, (c) 1st layer, (d) 2nd layer.

Figure 2 shows the block diagram of the designed seed-planter wheeled robot in terms of components interconnection. The robot has one microcontroller as the controller, three servos and 3 DC motors as the actuators and one line tracking sensor. This robot used three 4V batteries for all components, so the robot needs 12V power in total to run perfectly.

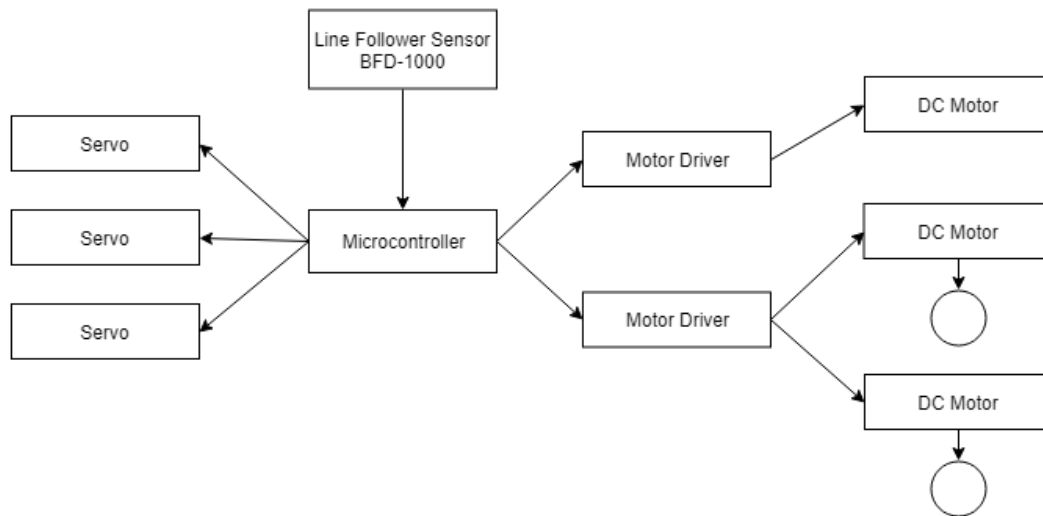


Figure 2. Block diagram of the Seed-Planter Wheeled Robot.

2.4. Methods and Working Principle

The algorithm used in this robot is a simple line follower algorithm. The robot used a line tracking sensor with five channels, namely outer-left sensor, inner-left sensor, center sensor, inner-right sensor, outer-right sensor and denoted by S_{ol} , S_{il} , S_c , S_{ir} , S_{or} . Each sensor will detect the line and the combination of detection is used as the input for the robot's microcontroller to define its task. The robot moves straight if only S_c tracks the line. Here, we assume that the robot tracks a straight line and its position is already centered, therefore, the robot should move straight by giving a same speed to the left and right wheels. If S_{il} tracks the line, we assume that the robot tracks a straight line but its position is a little bit too right, so the speed of left wheel should be lower than the speed of the right wheel. This way, the robot will turn slightly left. Similarly, if S_{ir} tracks the line, we assume that the robot tracks a straight line but its position is a little bit too left, so the speed of right wheel should be slower than the speed of the left wheel and the robot will turn slightly right.

To decide whether the robot should turn left or right, if S_{ol} tracks the line, it means that the robot sense a turn-left track, so the speed of the left wheel becomes slower than the speed of the right wheel. Similarly, if S_{or} tracks the line, it means that the robot sense a turn-right track, so the speed of the right wheel becomes slower than the speed of the left wheel.

In the case where no sensor can track the line, the robot must remember which sensor tracks the line prior to "lost track". If S_{ol} is the last sensor that detects the line, it is assumed that the line is on the left side of the robot, so the robot should turn left until it finds its track again. Similarly, if S_{or} is the last sensor that detects the line, it is assumed that the line is on the right side of the robot, so the robot should turn right until it finds its track again. When neither of the two sensor detect the line, it is assumed that the track is finished or some part of the track is erased, so the robot should move straight.

In order to do the task, the robot must stop when it encounters a "+" line. In this case, S_{ol} , S_c , and S_{or} must detect the line together so robot will stop and planting seed. In this case, the servo on its arm will switch scope to drill and the arm will go down slowly while the DC motor twist the drill to dig a hole. When the hole is dug, the arm will go up slowly and return to its default position and servo will switch from drill to scope again. Then, the servo on the bottom of seed container will open quickly to allow one seed to drop from container and slide through the pipe to the hole that has been made by the robot arm. When the seed has dropped, the arm will go down slowly while DC motor twist the scope to close the hole. When the hole is closed, the arm will go up slowly and return to its default position. Here, one task is finished and the robot will follow the track again. A flowchart that summarize the working principle of the robot is given in Figure 3.

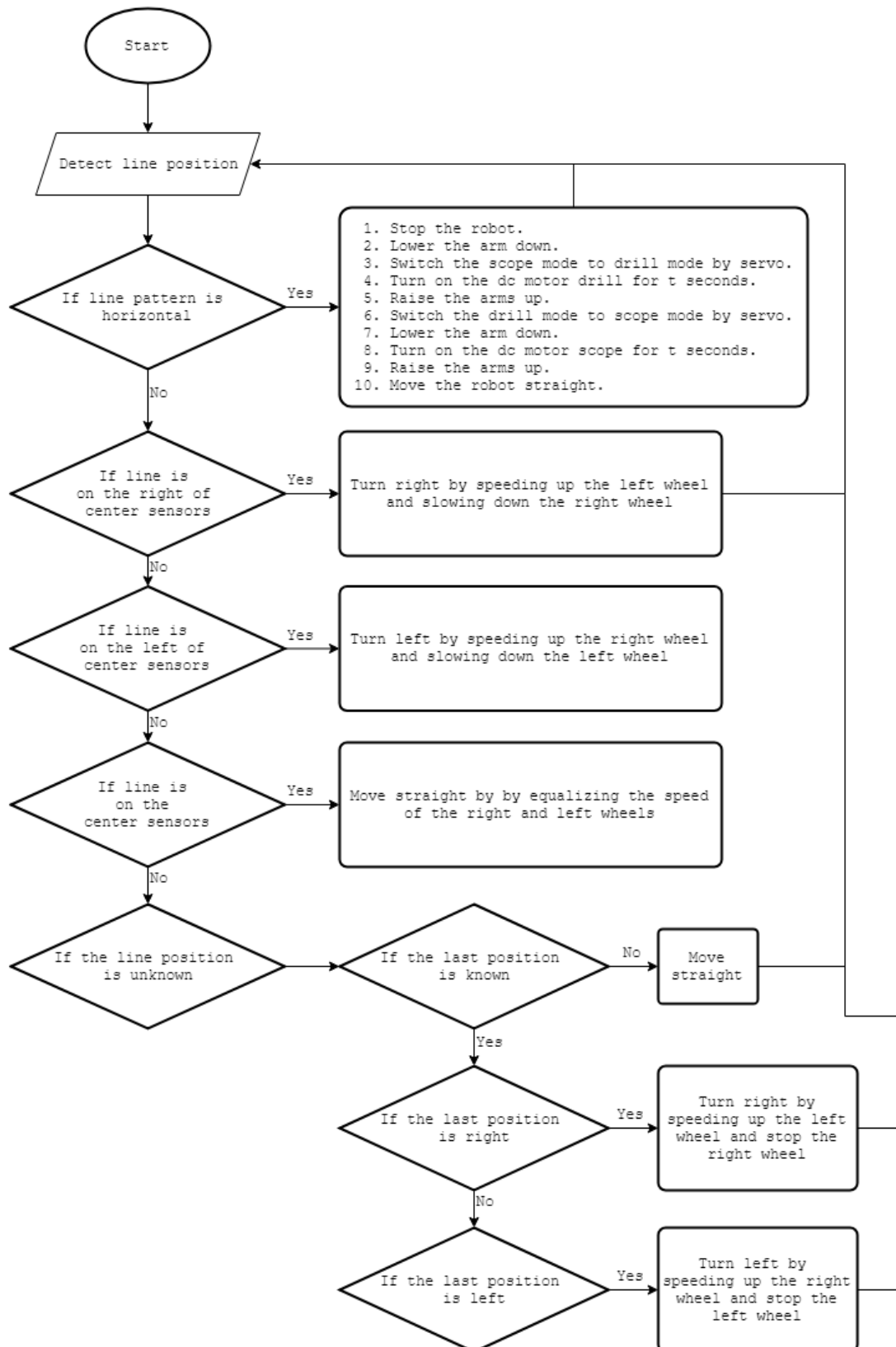


Figure 3. Flowchart of the Seed-Planter Wheeled Robot.

3. Robot Prototype

The prototype of the developed seed-planter wheeled robot is shown in Figure 4. Figure 4 (a) shows the front-view of the robot and Figure 4 (b) shows the side-view of the robot. The robot is built using acrylic chassis and wooden sticks. As designed, the robot has two motorized wheels in the left and right front side and one free-wheel in the center back of the robot to stabilize the robot. The robot is also equipped with a line tracking sensor, a seed container, and an arm.



Figure 4. Implementation of the Seed-Planter Wheeled Robot (a) front-view, (b) side-view.

4. Experimental Results

The initial experiment was conducted to check if all the requirements of the developed seed-planter wheeled robot can be achieved. Table 1 shows the overall performance of the robot based on its functionality requirements. These results indicate the robot successfully achieved all the required objectives as mentioned in section 2.2. The robot is able to do the following actions:

1. Move along the line
2. Stop when the robot detects a “+” line
3. Dig a hole
4. Drop the seed through the pipe to the hole
5. Close the hole again

Table 1. Functionality test.

Goals	Results
Robot can move along the line in the desired direction	Successful
Robot can stop when it encounters a “+” line	Successful
Robot can dig a hole for plant the seed	Successful
Robot can drop the seed into the hole	Successful
Robot can close the hole again	Successful

In this study, we also analyzed the effectiveness of the line following algorithm to different sizes (widths) of the track. In order to do this, a “circuit” was made as the experiment environment with black tape on top of a white ground / floor. The area of the circuit is $2 \times 1 \text{ m}^2$. In this experiment, 10 “+” signs were used to define the desired position of the tasks, where these “+” signs are distributed along the line. The experiment scenario and the initial position of the robot is depicted in Figure 5.

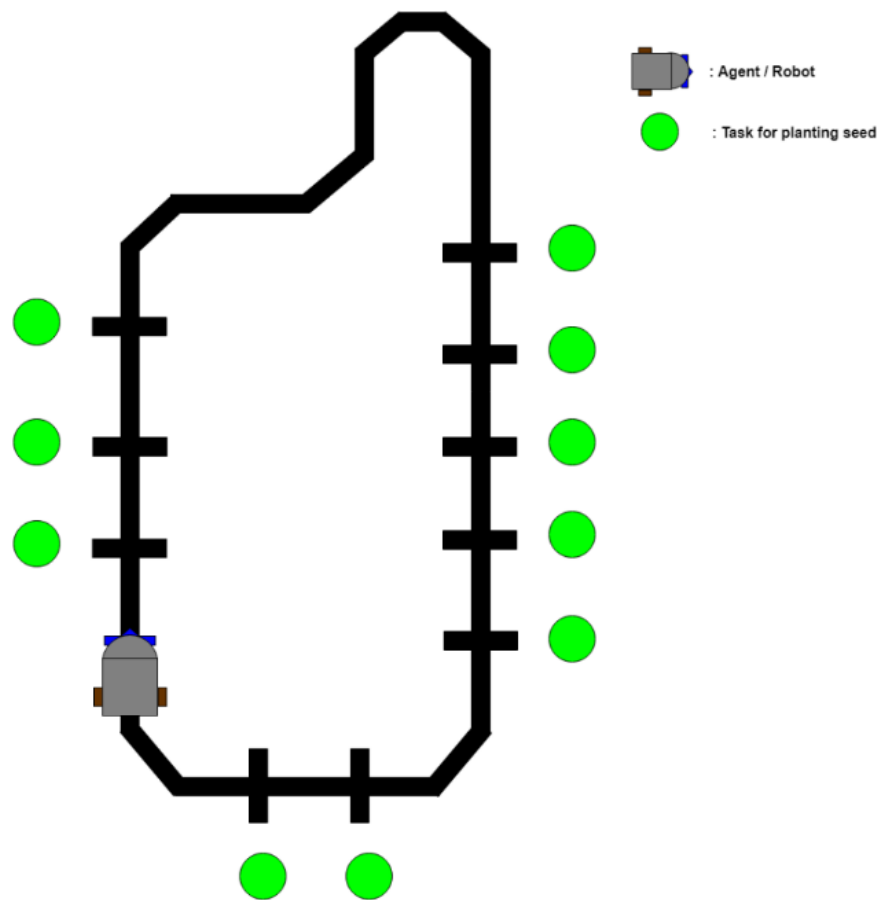


Figure 5. Experimental setup.

Table 2 shows the effect of track width to the robot movement stability. It can be concluded that the robot requires a track width of 3-5 cm to be able to move stably. This is due to the distance between each sensor channels and the distance between the line sensor and the robot center. If the line width is too far with sensor S_{ir} or S_{il} , then when sensor S_{ir} or S_{il} detects the line, the robot will turn sharply because the robot will try to make sensor S_c detects the line but the distance between sensor S_c and line is too far away. Figure 6 shows the distance between the sensor channels and the distance between the line sensor and the robot center.

Table 2. Track width vs robot movement stability.

Track width (cm)	Robot movement stability
1	Not stable
2	Enough
3	Stable
5	Stable

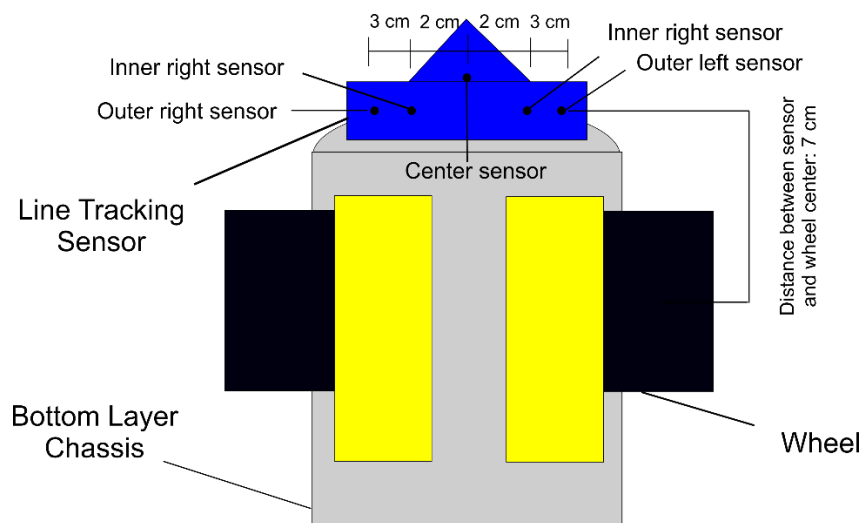


Figure 6. Distance between sensor with each other and distance between sensor with wheel center.

Table 3 shows the width of the track and its effect on the number of the successful task. Here, a task is considered as successful if the robot can dig the hole, plant the seed, and close the hole again, in the predefined location. In this experiment, we use ten “+” signs to define the task locations and experimented for several different track width: 1.5 cm, 2 cm, 2.5 cm, 3 cm and 5 cm.

Table 3. Results of the robot successful do the task.

Track width (cm)	Number of the successful task (max 10)
1.5	5
2	5
2.5	6
3	8
5	10

Table 3 indicates that the robot perfectly detects ten “+” lines when the track width is 5 cm due to the more stable movement (see Table 2). As the robot gets more stable, the number of the successful tasks is increased, and the optimum performance is observed when the track width is 5 cm (most stable movement).

5. Conclusion

In this paper, we presented the design of a single task-oriented wheeled robot for planting seed. The navigation of the robot was performed by using a line following algorithm which allows the robot to move along the line. The robot was also designed with the ability to perform a specific action: planting seed. Experimental results show that the robot has successfully achieved its defined requirements, that is: the robot can move along the line; the robot can stop when it detects a “+” line; the robot can dig a hole; the robot can drop the seed through a pipe to the hole; the robot can close the hole again. Experiments results also indicate that the most suitable track width for this purpose is 5 cm.

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