DESIGN AND DEVELOPMENT OF A SEED-SOWING ROBOT PROTOTYPE

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Abstract

This study aims to develop a small prototype of a seed-sowing mobile robot, that can follow the desired path, and be able to collect, carry and drop the object of interest (seeds) at the designated places. The robot utilizes an infrared (IR) sensor for detecting the desired line, while an ultrasonic sensor for detecting the desired drop location. These sensor inputs are processed by a microcontroller, which in turn sends the control signal to the dc motor for the line-following task. The microcontroller also sends the control signal to a group of servo motors (robot arms) to collect, carry and drop the seeds onto the crop border. The functionality of the proposed robot was tested in a lab setting, where the results validated the concept. This robot serves as a proof of concept for the seed-sowing robot application in the agriculture sector.

Keywords: seed-sowing robot, mobile robot, agriculture robot, line following, robot arm.

INTRODUCTION

Agriculture production is crucial for a variety of reasons. By producing more food, raising productivity has an impact on income, labor migration, and market expansion in agriculture. The allocation of limited resources is made more effective by increased agricultural output. Farmers now have the option to boost output while preserving the long-term viability of their farms' thanks to new approaches and procedures in precision farming. Precision farming is a concept of farm management based on the application of different technologies [1]. One of the emerging technologies is by introducing robotics for activities such as seed sowing.

A seed-sowing robot is a tool that assists farmers in saving time and money by helping to spread seeds at the desired location [2]. Various seed-sowing robots have been proposed to date. In [3], a seed-sowing robot was developed with seed spacing intervals and field area parameters as inputs. In [4], a field-based seeding robot was investigated using bullock cart-drawn planters. An agribot was in [5] to cut down on labor costs and time spent digging holes to plant seeds. A smartphone application for directing the movement of the created agribots was also presented in that article. In [6], an automated agricultural farming robot was developed for several farming tasks such as plows, seed sowers, pesticide sprayers, and soil and plant monitoring.

In this article, the design and development of a low-cost prototype for a seed-sowing robot are presented. The robot consists of a line-following mechanism that tracks the desired path of the simulated environment. This mechanism utilizes an infrared sensor for detecting the path and differential drive for locomotion. Meanwhile, for the seed-sowing mechanism, four degree-of-freedom (DOF) manipulator is designed using four servo motors. In this article, Section 2 presents the design of the proposed robot, and Section 3 presents the results of the validation. Meanwhile, Section 4 concludes the article.

METHODOLOGY

This section discusses the design of the seed sowing robot mechanism: line following and robot arm for seed sowing. The circuit connection of the proposed robot is shown in Figure 10. The line following system consists of an Arduino microcontroller, a motor driver, two 3.7V Lithium-Ion batteries, two dc motors, and three sets of infrared sensors/receivers. Meanwhile, for the robot arm, an Arduino microcontroller, an ultrasonic sensor, and four servos are used. The mechanism is presented in the following subsections.

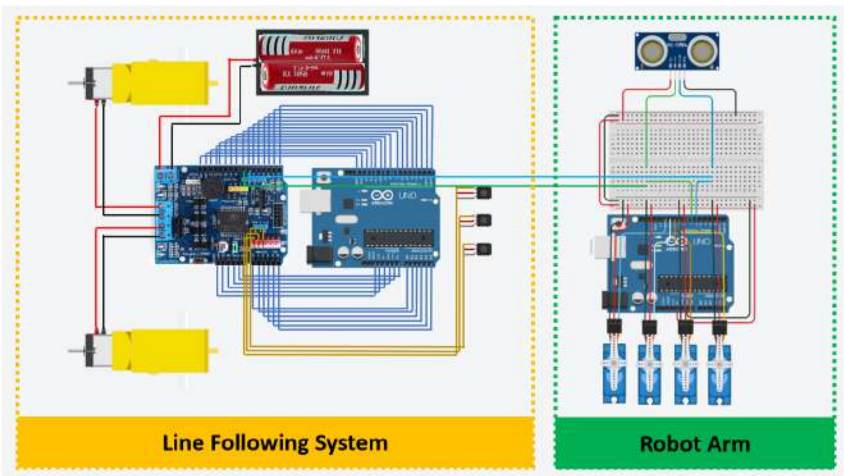

Figure 10: Schematic of the proposed seed-sowing robot.

Line Following System

The line-following system utilizes three infrared sensors to detect the desired black line. Each is positioned in front of the robot, side-by-side, and are responsible for detecting black line for the left, middle and right portion ahead of the robot respectively. When detecting the surface, inputs from infrared sensors with an 8-bit analog-to-digital converter of the microcontroller will be >500 for black, while <500 for white detection. A single sensor outputting a value of >500 indicates that the robot should go in that direction, while if two adjacent sensors output a value of >500, the robot is ordered to go in that direction, albeit slightly. If all three of them output>500, the robot will stop moving.

An ultrasonic sensor accompanies the system, adding a stopping functionality for when a 'sign' was detected. The 'sign' here refers to any obstacle and acts as an indicator of when our seed-sowing robot should start planting. In accomplishing that, the ultrasonic sensor was positioned to always face the left of the robot, and the 'sign' is positioned outside of the track, as the robot arm will operate on the inner side of the track, planting seeds during the time the robot was stopped. The stop was delayed to 13s for robot arm operation, after which the robot will move forward slightly to move out of the 'sign' range and proceed back in following the track.

Robotic Arm

In this study, a robotic arm is designed as shown in Figure 11 for picking up and dropping the seeds for sowing. This robot arm consists of four servos that can be controlled by the microcontroller. After setting the servos to reset position (0^o), several wooden sticks are used to connect them. Also, the last servo is used as a gripper. Then, the robot arm is placed on the robot platform presented in Section 2.1. For picking up and dropping the seeds at desired locations, the trial-and-error method is used to find suitable servo angles.

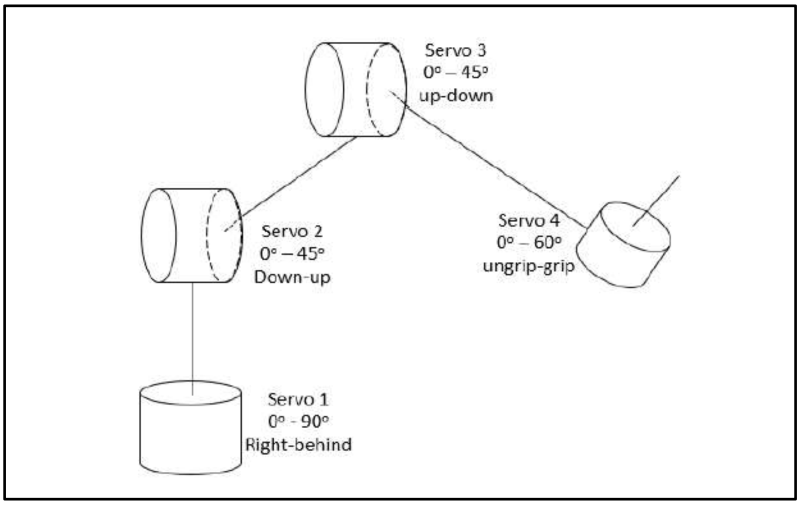

Figure 11: Schematic design of the robot arm.

RESULTS AND DISCUSSION

To test the proposed seed-sowing robot design, an experiment was carried out in a simulated farming environment as shown in Figure 12. The track was designed with an enclosure positioned in the inner part of the track, filled with soil to emulate a planting environment. On the outer track part, a pole was positioned at a point, acting as the 'sign' for the robot to start its planting operation. The basket containing 'seeds' are positioned in the back of the robot, on top of the battery holder. It is expected that when the robot is positioned in front of the pole, the ultrasonic sensor will detect the pole, stopping the robot from moving along the track. The robot arm function will then start, moving the robot arm, and taking the seeds from the basket before dropping them in the enclosure. After that, the robot will resume its line-following function, moving along the tracks until again the pole was detected, and this repeats indefinitely, or until the battery is depleted.

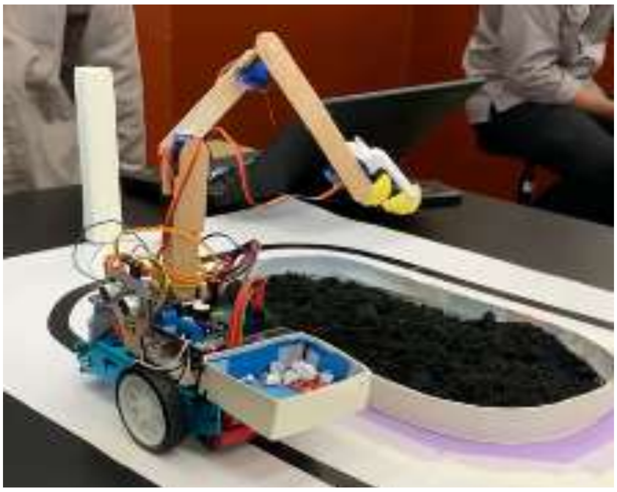

Figure 12: The proposed seed-sowing robot in a simulated environment.

During the experiment, it is found that the robot moves exactly as we expected, albeit with some slight errors. The expected movement was achieved, as the robot travels along the track, and stops when it is in front of the pole, after which the robot arm moved, grabs the 'seeds', and drops them into the enclosure. The errors, on the other hand, vary, with one error being the robot having traveled off-track. This occurs randomly after the robot tries to resume its line-following function. This was expected, as the robot was programmed to move straight a little after the robot arm function was done, to move away from the obstacle, and awkward stopping (i.e., not straight) may result in off-track. Another error was that certain servos may not work during the robot's arm movement. This was not expected of us, but still, we managed to find the cause, which was due to the servo having some faults.

Following that, we believe that improvement could be made on the robot, particularly the programming so that off-track could be avoided. This could be done by implementing a PID controller to ensure the robot is positioned precisely when stopping. The servo matter could simply be improved by replacing the servo with a brand-new, perfectly functioning servo. Other than that, we believe that our robot's function well as intended. Certain improvements could also be made to the design, as our robot currently only carries out the sowing function and having a tilting function will surely better complement our robot's capabilities.

CONCLUSION

To summarize, agriculture plays an important role in the economy as well as is the backbone of the economic system for developing countries. For decades, agriculture has been related to the production of vital food crops. Promoting sustainable agriculture is one of the ways to achieve the Sustainable Development Goal (SDG) which is SDG 2: Zero Hunger. To achieve this, we propose a low-cost seed-sowing robot that consists of a differential drive mobile robot platform and robot manipulator. Through an experiment, it is found that the proposed robot is functional and able to carry out the programmed task successfully. This serves as a proof of concept for the development of the seed-sowing robot. Future works involve the improvement of the robot arm mechanism using a bigger platform.

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