Multipurpose Agricultural Robot Platform

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Abstract. During the last decade, agricultural sector has witnessed a wide adoption of cutting edge technology not only to improve the quality and quantity of the crops but also to ease the labour burden. These technological oriented and innovative agricultural solutions have opened new horizons for opportunists, researchers and investors along with the creation and development of new markets. Robotic and automation technologies are now complementing farmers in various ways. In this paper, we present the mechanical and electrical design of multi-purpose agricultural robot which has the capabilities to move in three Cartesian coordinate axis along with the functionality of harvesting small sized fruits with the help of grippers. Our developed robot prototype can be controlled via remote control. Prototype testing results show that the developed robot can reach to the target by passing any small sized obstacle and harvest the fruit. We believe that such low cost, less complex and indigenously developed multipurpose agricultural robots can help farmers by reducing their labour cost and human effort.

1. Introduction
The agriculture industry provides the world with one of the most basic needs: Food. “End hunger, achieve food security and improved nutrition and promote sustainable agriculture” is the second sustainable development goal of the United Nations (UN) by 2030 [1]. Countries like India, Thailand, Pakistan etc., where a vast percentage of the work force is associated with agriculture-related sectors contributes less than 10% of the gross domestic product (GDP) to the country’s economy [2]. In Thailand, more than 28% of the total work force is associated with agriculture either directly or indirectly. Interestingly, the dominant portion of the agricultural labour force aged more than 40 years with less youth adopting this hard profession [3]. The off-balance problem between labours and agricultural product values and the rise in the proportion of the older workers is impacting production negatively. The labour shortage along with the increase of world population essentially needs technological advancements to meet growing and shifting demands. There has been a dramatic shift in...
the use of technology in the agriculture industry in the last decade, however, farmers from the developing countries are still lacking in modern tools usage primarily because of cost, unavailability of products in local market and inadequacy of education. Human force is generally used for all the steps of crop growth starting from sowing, irrigation, monitoring the growth, pest control and harvesting. The demand for food is outpacing available farmland and robotic application such as agricultural robot is one of the ways that helps farmers to close this gap. The agricultural robots are increasing production yields for farmers in various ways where the drones are used to analyse the condition of farming environment and autonomous tractors for sowing, mowing, fertilizing, etc. and robotic arms to planting, harvesting and picking, the technology is being deployed in creative and innovative applications. Agricultural robots carry out slow, repetitive and dull tasks for the farmers, allowing them to focus more on improving overall agriculture production yields. Some of the most common robots in agriculture are used for harvesting and picking, weed control, autonomous mowing, pruning, seeding, spraying and thinning, phenotyping, sorting and packing. Among these, harvesting and picking is one of the most popular robotic applications in agriculture due to the accuracy and speed of the robots can achieve to improve the size of yields and reduce waste from plants being left in the field.

In this work, the aim is to build a strong mobile prototype structure of an agricultural robot. The robot will perform harvesting and picking small fruits by the help of the driving system that is designed to support the robot to be stable on the different kinds of soil surface condition. The robot will also be used for many other agricultural functions in the future by installing the desired additional applications such as watering, sowing seeds, spraying pesticides in the system.

2. Overall System Design

Overall system design is constructed mainly by mechanical system design and electrical system design as shown in Figure 1. The mechanical part is responsible for the movement of robot in three axis which is done with the help of motors and wheels. In addition to the movement, mechanical system is also responsible for governing the harvesting system i.e. plucking the fruit from the plant. The electrical system works in collaboration with the mechanical system. The electrical system is responsible for switching ON and OFF, speed up and down the motors which are installed in the robot which facilitates the robot to move in X, Y and Z directions. The Electrical system is also responsible for establishing a communication channel between the remote control and the Arduino. The details of each system design will be discussed in the following sections.

**Figure 1.** Overall System Design of the Robot.
The platform structure, which is shown in Figure 2, has a size of 120 x 105 x 96 cm and weighs 60 kg to fit the fruit plot and is high enough to attach accessories without colliding with the plants.

![Figure 2. Overall Platform Structure of Robot.](image)

3. Mechanical System

In the design of robot structure, aluminium profile is chosen as it can be easily constructed for desired structures due to its flexibility, durability and light weight feature. For mobility, the robot has four wheels in total: two rear wheels each having 8 inches diameter along with DC motors for drive system and two 10 inch diameter front wheels with Brushless DC (BLDC) Hub motors for turning. There is a gripper to harvest fruits at the middle of robot that can be moved with the help of Y-axis and Z-axis modules.

3.1. Front Wheels

The front wheels are used for turning the robot with the help of motors connected to the belt. The turning degree of wheel is important to consider because the inside wheels must have more turning degrees than the outer wheels. If both wheels turn at the same angle, the inner wheels will cause stings and trying to push the robot head out of the turning circle causing the wheel to slip and the turn is not smooth.

From the calculations in Figure 3, it was found that when making the inner wheel to have the maximum turning degree at 50 degrees, the outer wheel must have a turning angle of about 27 degrees to allow the wheel to rotate smoothly and not to slip.

3.2. Rear Wheels

The rear wheel are used to move the robot forward and backward by controlling BLDC Hub motor. Aluminium profiles support to hold the wheel next to the frame of the robot handling the weight of the robot on both sides.

3.3. Z-Axis Module

For Z axis, the “Lead Screw” mechanism is used for up and down movements which needs to be a lot more precise than Pinon belt. A lead screw has a thread optimized for reducing friction and is used frequently in many applications. Precise positioning and non-overhauling can be obtained with a shorter lead, however, the main downside of lead screws is that they are mechanical inefficiency converting 20% to 80% of the applied torque into linear thrust and rest of the energy is wasted in the form of heat [4]. Furthermore, the lead screw mechanism is made self-locking as well which will prevent any accident or damage to the fruits.
3.4. Gripper

For the purpose of harvesting fruits, we used the gripper to pull an orange fruit out of the plant which can be done by the handle attached with servo motors and this can move on 2 axes in the plane. The clamping area can be opened to clamp the orange fruit using force to pull the orange fruit not more than 10 Newton. It will cause the orange fruit to fall out of the plant and no bruises on the orange fruit. Since two main parallel surfaces of contact are used, the fruit suffers from high concentrated compressive force. In order to distribute this force, taking into account the variation in size and shape of the strawberry the contact surfaces must be increased [4]. This solution is obtained through the simulation that when each side of the handle receives different forces which will cause the handle to damage the fruit or not. The designed gripper for the platform is shown in Figure 4.

4. Electrical and Control System

Components of electronic circuits used to control the robot are shown in Figure 5. For controlling the robot, it will use the manual system controlled by the Futaba brand remote control with all 6 channel values which can be divided as follows: Channels 1 and 4 can move freely in the horizontal direction. Channels 2 and 3 can move freely vertically. Channels 5 and 6 can move only 2 strokes which is up and down. System controls the front wheels consists of 2 DC Motors, 2 Motor Drive VNH2SP30 and 2 potentiometers. When Arduino receives a signal from the receiver, Channel 1 will take control of motor rotation direction attached to the front wheel. Based on Figure 3, knowing that both wheels must rotate at unequal speeds. For such conditions, the installation of a potentiometer into the front wheel turning mechanism makes it possible to know where the wheels are. After that, the Arduino board receives signals from the receiver and sends the signal to the VNH2SP30 board to control the speed of each motor. When the wheel spins continuously, the potentiometer will dictate to which extent each wheel can rotate. The control system for Y-axis and Z-axis modules consists of two NEMA17 stepper motors, two A3967SLB Stepper Motor Driver T and 4 limit switches. The motor is used as a bipolar type stepper motor so it requires a dedicated board to control, when the board runs at one loop, the motor will rotate about one pulse. In this case, the NEMA17 stepper motors will rotate about 1.8 degrees per 1 pulse. Therefore, the Arduino board is used to receive signals from Channel 3 for the Z-axis and Channel 4 for the Y-axis. After that, the values will be used for output mapping of the signal to the motor to control the motor speed for the intended operation. In addition, there are 2 limit switches for the Y-axis and two for the Z-axis to determine the movement of the motor and prevent the damage that may occur. Control system for the rear wheels contains 2 controller boxes, 2 BLDC Hub Motor. The rear wheel, which acts as driving wheel, has a brushless DC motor. The handle consists of 2 Servo Motor, MG955 that determine the position of the handle can be controlled by ordering directly through the Arduino board. Arduino takes the value obtained from mapping process and then orders a servo motor via digital channel to get desired degree rotation. In the second motor, only the value received from Channel 2 will be used to control the position of the motor at 130 degrees (the handle will open) with 180 degrees (the handle will close) only. A 72 MHz receiver is...
used to send the signal from the remote control to Arduino board and connect the receiver’s output into the digital input of the Arduino board.

![Wiring Diagram](Figure 5. Wiring Diagram for Electrical and Control System)

5. Prototype Testing
In basic test, the basic abilities of the robot are tested one by one. The test is divided into 5 main parts: (1). Testing the robot if it can run in a straight line. To do so, both rear wheels must rotate at the same speed and force the front wheels to be parallel to facilitate robot run. The distance of this test was approximately 5 meters. (2). Testing the robot if it can turn: it was done to verify that the principle and the results obtained from the calculation in Figure 5 can be used and check that both wheels at the front can be moved without any skidding. Along with finding the minimum radius of curvature that is estimated so that the robot can do when the inner corner of the wheels at the turn that has a value of 50 degrees. (3). Testing if the robot can cross obstacles: this test is done to verify that the robot has enough power to run across small obstacles and test the impact reduction of the vibration reduction system installed on both front wheels. (4). Testing if robot can park or stop in the designated area: it was done to check the driving system of robot that can move in a desired location. In this test, the robot moves for a distance of about 6 meters and can be stopped in the specified area. (5). Testing Y-axis and Z-axis modules of the robot: the test was done to verify that the two control motors can move smoothly and find the working area of the Y-axis and the Z-axis module using the limit switch to determine the extent of all movement. Overall testing which is a test to see the overall ability of the robot form a stationary position to do harvesting in a specified time. The score criteria for overall testing is shown in Table 1. All the example of the test is shown in Figure 6.

| Criteria used | Score | Remark |
|---------------|-------|--------|
| Able to collect fruits | 2 | | |
| Damage | -1 | With a stick or bruise, etc. | |

| Performance | Score | Remark |
|-------------|-------|--------|
| Excellent | 10+ pts | | |
| Good | 7 to 9 pts | | |
| Fair | 4 to 6 pts | | |
| Poor | 0 to 3 pts | | |

(a) (b)
6. Discussion and Testing Results

Based on various tests in Section 5, the results of the tests are shown in Table 2. Total score is 8 points from the criteria considering that the test result was good.

| Testing                                                       | Result | Remark                                              |
|---------------------------------------------------------------|--------|-----------------------------------------------------|
| Basic Testing                                                |        |                                                     |
| Can run in a straight line at the specified path             | Pass   | 1.5 meters length                                   |
| Can turn                                                     | Pass   | The radius of curvature is about 1.4 meters. (Measured from the middle of the robot) |
| Can run across obstacles that are simulated to compare with rough areas | Pass | acrylic sheets about 2 cm high are used as obstacles |
| Can park or stop in the designated area                      | Pass   | The area is approximately 1.2x1.5 meters.           |
| Can move the Y axis and the Z axis module without interruption| Pass   |                                                     |
| Overall Testing                                              |        |                                                     |
| Test all parts at the same time and collect fruits           | 8 points | Can collect 4 fruits without damaging them          |

7. Conclusion

In this paper, we designed a multipurpose agricultural robot. The indigenously developed has two main parts and they are the mechanical system and the electrical system. The robot platform structure mainly uses aluminium profile material due to strength, durability, corrosion resistance, flexibility and lightness. This research work presents a preliminary study on the part of harvesting fruits using Orange as an example. The developed prototype was rigorously tested and form the test results, it can be found out that the robot can perform basic tasks like moving forward, backward, turning left and turning right according to the intended purpose using two rear wheels for driving system and two front wheels for turning the root. Also with the help of Z-axis module, it can harvest fruits which are not very large by size. The platform of this versatile robot for agriculture is designed with a purpose to be a model for further development in the future, such as putting more various agricultural functions and also the introduction of image processing technology to enable robots to work automatically with precise positioning of the robot etc.

8. References

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