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# Multi-Agro: Design and Development of a Cartesian-based Self-Plantation Robot for Home-Scale Gardens with Mobile App

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**Abstract.** The increasing diversion of agricultural land in Indonesia has not been followed by a decrease in the need for food in society. This change in agricultural land use poses a serious threat to food security. To solve this problem, a home-scale farming tool called Multi-Agro has been developed, which can planting independently and automatically. This tool uses a cartesian method-based robot manipulator to determine the exact coordinate points during the planting, maintenance, and harvesting process of the plants. Plant watering time can be set on the app automatically so that plant health is maintained. In addition, a weed detection system using a camera can also improve plant health. With the automatic system and monitoring that can be accessed through the app, this independent farming becomes more efficient and does not require much time from agricultural actors. Based on the experiment conducted in a real-physical miniature model of home-scale farming it can be concluded that the proposed project has a significant improvement in smart urban farming. Hopefully, this research can help to overcome the increasing need for food even though agricultural land is increasingly limited.

## 1 Introduction

Currently more than 50% of the world's population lives in cities or downtown, and predicted by 2030 it will reach 80% [1]. The urbanization process leads to an increasing demand for food, especially in urban areas. However, the conversion of agricultural land in urban areas is increasingly prevalent today [2]. Agricultural land conversion is the process of shifting the function of agricultural land from agricultural use to other uses, on part or all of the land area which generally has a negative impact on the environment and on the potential of the land.

In general, the rate of land conversion is associated with the rate of population growth which results in increased fulfilment of needs based on land use, such as settlements and other public facilities. The process of land conversion is unavoidable in every developing region. Developing regions usually have a high population growth, followed by an increase in the need for land for settlements and other public facilities including for industry [3].

Agricultural land, especially paddy fields, is the land that has experienced the most conversion of functions. Changes in the use of agricultural land are a separate threat in achieving food security [4]. From the Badan Pusat Statistika (BPS), food crop production in Indonesia continues to decline every year [5].

One of the factors causing the decline in food crop production is the transfer of land from agricultural land to non-agricultural land. Reflecting on these problems, the idea of making Multi-Agro was born where one of the sectors that was focused on was plantations. It is called a self-planting robot with the aim that food crops can be planted independently by individuals by utilizing existing technology so that it does not require a lot of time and effort considering that the average population in Indonesia according to the Badan Pusat Statistika (BPS) works for 40.96 hours per week, so that if you grow your own traditionally it is not possible [5].

Self-plantation robot here is designed to be able to carry out planting with several basic treatments so that the yield can be maximized. With board media for planting, several coordinates will be set for the planting point by utilizing the use of a motor, the robot can have 3 axes to reach all parts of the media. Determination of the coordinates themselves uses a method commonly called the Cartesian method whose working principle is almost the same as the concept of a robot manipulator. Vacuum technology will be used here for the process of planting seeds at predetermined coordinates. Assisted by the Arduino and Raspberry microprocessors, this tool will be able to monitor the process using a simple mobile application. Where the data that has been obtained from sensor readings will enter the cloud and will be read by the application.

As more people move to cities, the agricultural area is being converted into urban areas. This has led to a reduction in land available for gardening and traditional farming. Robots for home-scale gardening offers a solution by enabling individuals to grow crops

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efficiently in limited spaces, such as balconies or rooftops, in urban environments. By integrating robotic technology into lawn care, it is hoped that the innovations that homeowners can gain several benefits, including time efficiency, better plant maintenance, and increased resource efficiency.

## 2 State of The Art

In this research, a combination of several idea in intelligent urban farming is carried out by regarding the successful of previous researches such as conducted by [6], [7] and [9]. These inspirations had been combined in this research and enhancing with a function of remote monitoring and automated farming via a mobile system such as in [8]. Once the physical system like the automation in urban farming carried out onto the web users can easily manage the farming everywhere and anytime.

## 3 Materials and Methods

This section describes the methodology used to implement the proposed robotic solution, as well as the various materials and inputs used.

### 3.1 Self-Plantation Robot Design

This robot uses linear movement in three position axes (X, Y, Z), with the length of each axis being X = 830 mm, Y = 1230 mm, and Z = 800 mm. The mechanical structure consists of several parts that need to be assembled and calibrated according to the desired design. The robot moves on an aluminium profile, which allows it to move smoothly and experience minimal friction. The components of the robot design can be seen in the Fig. 1. and explained as follows:

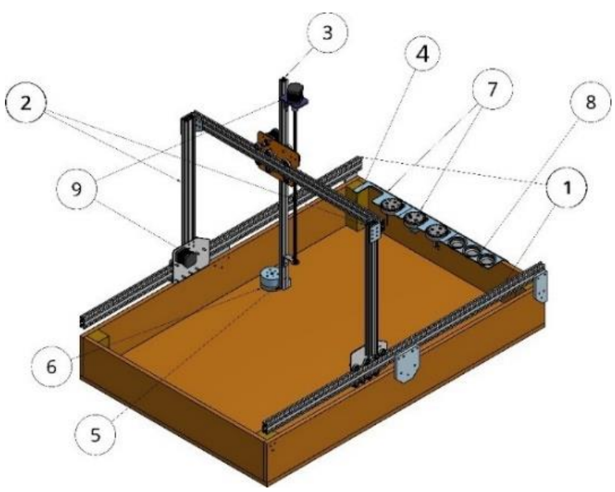



**Fig. 1.** Self Plantation Robot Design

**Table. 1.** Descriptions of Self Plantation Robot Design

| **No.** | **Descriptions** |
|---|---|
| 1 | X-axis gantry track : Aluminum profile that supports the movement of the robot in the X-axis direction. |
| 2 | Y-axis path support : Consists of an aluminum profile that serves as a support for the robot's movement in the Y-axis direction. In geometric form, it can be likened to a lifting bridge connecting two X-axis profiles that in turn support the robot's Z-axis and electronics box. Movement on the path support allows reaching the Y coordinate in Cartesian Position (Z, Y, X). |
| 3 | Z-axis gantry track: Aluminum profile that supports the movement of the robot in the Z-axis direction. |
| 4 | Y-axis gantry track: Aluminum profile that supports the movement of the robot in the Y-axis direction. |
| 5 | Tool Holder: A tool holder for mounting tools to perform different jobs, located at the lower end of the Z-axis. |
| 6 | Camera: Camera for weed detection, located next to the tool holder. |
| 7 | Tools Bay: contains tools on the robot. Using magnets to be attached |
| 8 | Seeds Bay: a place that contains plant seeds that will be planted |
| 9 | Stepper motor: actuators to move the robot parts |

The detailed size of the self-plantation robot can be seen in the Fig. 2 as follow.

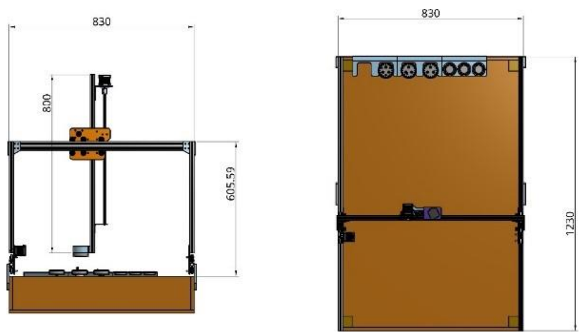



**Fig. 2.** Dimension of Self Plantation Robot Design

### 3.2 Hardware Design and Construction

The self-plantation is scheduled to be active for 24 hours and performs a series of processes. The cycle starts with seed planting to treatment until harvest time arrives, several systems in every 24 hours are:

a. Receiving and sending data from sensors to the cloud.
b. Processes the images before they are processed by one of the Convolutional Neural Network.
c. Generate and forward commands to actuators.

The purpose of data processing in the current system is to determine the threshold of moisture content in the soil, determine the irrigation dose for each individual plant so as not to overwater the plant, and periodically monitor the plants for maximum harvest.

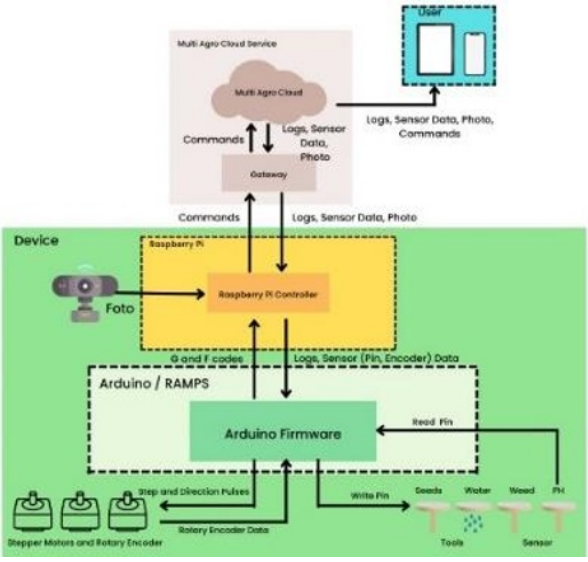



**Fig. 3.** The system design proposed

Details on the control part of this self-plantation robot can be seen in Fig.4. where Arduino uno as a microcontroller connected to CNC Shield. In CNC Shield, the DRV8833 motor driver is placed as the driver of each stepper motor that works in each axis. While the 2-channel relay module here will function as a state regulator of the tools on the robot, such as activating the vacuum when planting seeds, then activating the dc motor for plant watering needs. This 2-channel relay module will enter the digital pin CNC Shield which is connected to Arduino uno.

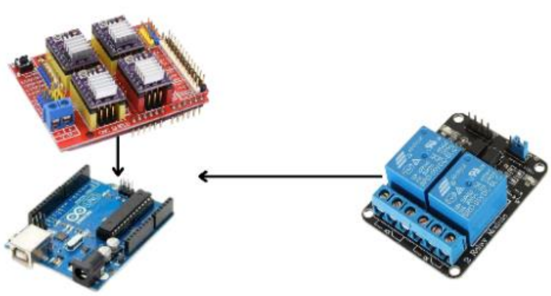


**Fig. 4.** Details on Self Plantation Robot Control

### 3.3 Robot Working System

In the self-plantation robot, the seed planting system is carried out automatically using a roller system with a motor for each axis located on the side of the planting medium and the aluminium frame of the robot. Each process carried out by this robot uses a different tool head. For the seed planting process, the tool head used is vacuum because to take seeds is done with a suction or vacuum system which then the robot will move to the planting coordinates and insert the seeds into the soil at those coordinates. In the watering process also has almost the same concept, it's just that there is a change of tool head because for watering there is its own so that in the design for this tool head the water can spread evenly and the mineral content of the plant can be said to be sufficient. For more details can be seen in the flowchart below.

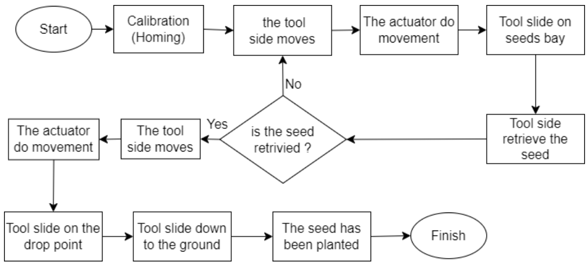



**Fig. 5.** Seed Planting Flowchart

The seed planting process will begin with the robot performing a calibration process (homing) to reach point 0 then the seed tool robot will aim above the seeds bay to take the seeds by sucking the seeds. When the seeds are successfully taken, the tool side will move to the planting point according to the existing coordinates and will go down to the ground to plant the seeds.

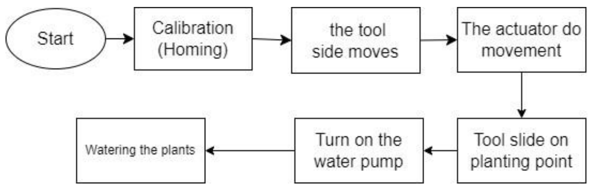



**Fig. 6**. Watering Flowchart

In addition to planting and watering, this tool will perform treatments such as periodically checking the soil moisture at the coordinates where the seeds have been planted. To maintain this moisture, if the coordinates that are checked are detected to be less moist, then proceed with the action of the plant watering process at that coordinate. In this robot, there will also be an app to support the effectiveness used as monitoring. Planters will be able to determine which points to plant so that they can have many options for planting layouts and seeds. When the seeds have been planted, the user app can monitor how the soil moisture was the last time the robot watered, then the health of the plants will also be displayed in the app.

### 3.4 Cartesian Method

Robot manipulators have basic structures such as cartesian, cylindrical, polar and angular configurations. Cartesian configuration states that the position of a point is done using cartesian coordinates (X, Y, Z), where the value taken by the end of the arm is a shared variable, corresponding to the coordinates. The cartesian method will be used as a robot mechanical system where the robot movement will be linear or prismatic in all three (X, Y, Z). Calculations using the cartesian method are used in determining the coordinates on the planting board, later each coordinate that has been determined on the planting board will become a seed planting point. Using the cartesian method or coordinates this robot will be able to determine automatically when planting. The use of the Cartesian method itself is inspired by its accuracy in the movements that can be done using this method and the ability to adapt to the size and app of planting board [6].

## 4 Apps

The system of this self-plantation robot has 3 stepper motors for the X, Y, Z axis with 4 sensors, each consisting of 3 limit switches. The sensors mentioned earlier will be connected and controlled through Arduino Uno which is then communicated with Raspberry Pi 4 using serial. Raspberry Pi 4 is used to detect weeds in the field where the detection results will decide the action of the destroyer for the weeds themselves. Data from sensors will be channelled to the cloud connected to the app so that it can be monitored in the app. As a database requirement in this research, utilizing Firebase as a data storage and communication from the microcontroller on the device with the smartphone app. Firebase itself is **mBaaS** (Mobile backend as a service) which means Firebase provides various services that will be provided in various backends for smartphone apps such as databases, notifications, machine learning, analytics, and so on. In this research, what is used is a database as a store of sensor values sent from the microcontroller [8].

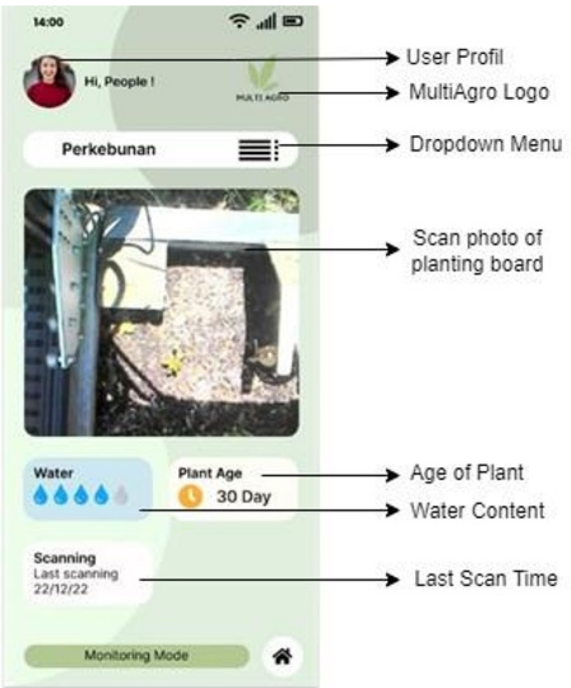



**Fig. 7.** Display of monitoring screen

The process of making apps begins with the selection of software and the usefulness of future apps. Because of the increasing number of iPhone users in Indonesia, the making of this app uses Flutter where one of the advantages of Android Studio is that when making apps it can be directly used for IOS, Android, and Web platforms [8]. The first step is to create a User Interface which is one of the important aspects in the app and can support user interest later. There are several menus offered for this self-plantation robot, as shown in Fig. 7.

On the monitoring screen there is some information that the user will get, such as soil moisture contained in the water menu indicated by several levels. In addition, there are the results of the last monitoring scan and when the monitoring was carried out. In addition to the monitoring menu in this app can also be used to plan seed planting, starting from selecting the row to be planted and which seeds to plant for that row as shown in Fig. 8.

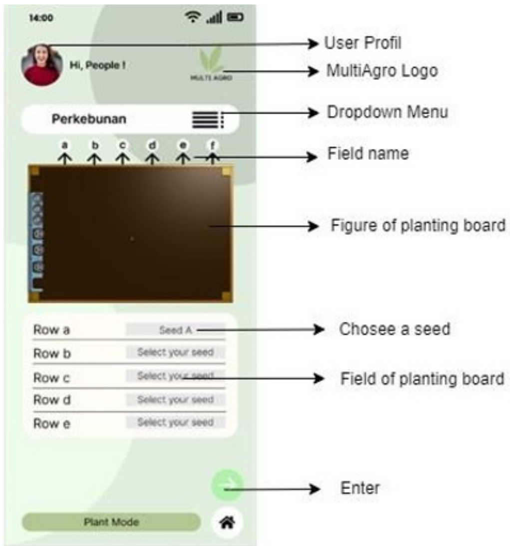



**Fig. 8.** Display of control screen

## 5 Results and Discussion

### 5.1 Realization of the Planting Board

In the realization process of the 3D design contained in the previous chapter, the self-plantation robot is made from plywood with a thickness of 1.5 cm. As for the track and gantry, it uses aluminium profile $20mm \times 40mm \times 1230mm$ for the track and $20mm \times 40mm \times 830mm$ for the Y-axis and $20mm \times 40mm \times 700mm$ for the Z-axis.

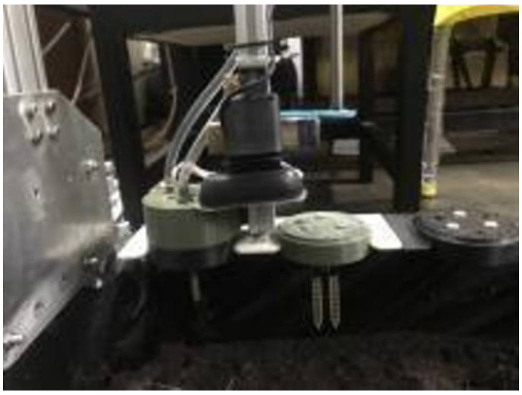
(a) (b)

**Fig. 9.** Media Planting Place

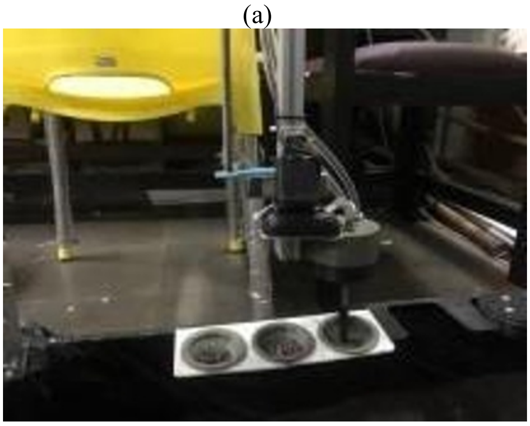
After the mechanical assembly of the self-plantation robot is carried out, it will continue with the stage of giving soil and electrical design. In the current case the installed electronics are not what they should be, because before they are completely refined the self-plantation robot will go through a trial process with several electronic components that have been proposed previously. The robot's mechanical transmission uses toothed belts and corrugated pulleys, which result in smooth movement on the axis. This transmission does not require ongoing maintenance and can work efficiently in humid environments with varying temperatures. The cable system is housed in a flexible cable carrier, which reduces wear and tear and protects it from sunlight and water.

## 5.2 Timing of Planting Robot's Movements

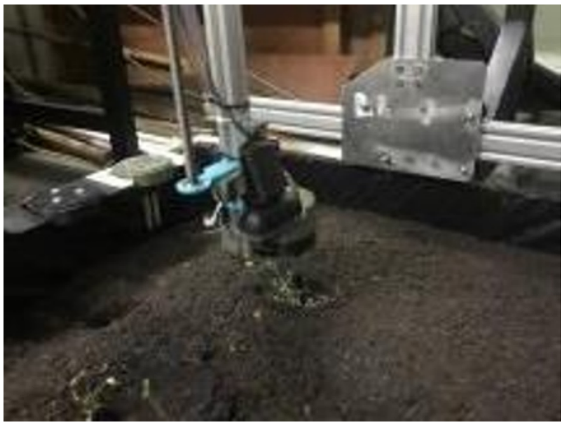
Robot's movements are carried out by giving commands from a python program that can be accessed through the MultiAgro app. In the planting test, the time is measured for each planting, while the distance of the vacuum tool to the seed is ± 1mm. In this test, the researcher made a determination where the vacuum tool will go down as far as - 324mm from point 0 of the Z axis to take the seeds contained in the seed bay, then will go up to point -200.32 for the Z axis and walk to the planting point, finally the vacuum tool will go down to plant seeds as far as -440mm from point 0 of the Z axis, which means the depth of the planting point is 25mm below the surface of the land, for the process can be seen in Fig. 10.



(a)



(b)



(c)

**Fig. 10.** (a) (b) (c) Processing of planting the seed

Table 2. is a planting test by measuring the time at each planting point and carried out at 9 planting points.

**Table. 2.** Measurement data of planting the seed

| No. | Position | Time (sec) |
|---|---|---|
| 1. | Vacuum tool picks up seeds | 09.60 |
| 2. | Planting seeds at point A1 | 08.37 |
| 3. | Vacuum tool picks up the seed | 08.52 |
| 4. | Planting seed at point A2 | 07.68 |
| 5. | Vacuum tool picks up the seed | 08.73 |
| 6. | Planting seed at point A3 | 08.96 |
| 7. | Vacuum tool picks up the seed | 08.86 |
| 8. | Planting seed at point B1 | 10.13 |
| 9. | Vacuum tool picks up the seed | 09.07 |
| 10. | Planting seed at point B2 | 09.18 |
| 11. | Vacuum tool picks up seeds | 08.98 |
| 12. | Planting seed at point B3 | 08.99 |
| 13. | Vacuum tool picks up the seed | 08.48 |
| 14. | Planting seed at point C1 | 12.08 |
| 15. | Vacuum tool picks up seeds | 10.31 |
| 16. | Planting seed at point C2 | 09.81 |
| 17. | Vacuum tool picks up seeds | 10.13 |
| 18. | Planting seed at point C3 | 09.93 |
| Total Timing | | 149.96 |
| Average | | 08.33 |

The time required to complete the seed planting process is about 2 minutes 30 seconds for 9 planting points at a moderate speed. The time required is quite fast. But sometimes the robot is unstable at high speeds.

## 5.3 Timing of Watering Robot's Movements

The watering process is carried out based on a predetermined real time, twice a day. Watering tests are carried out by giving commands from the python program. In the watering test, the time is measured for each watering, while the distance of the vacuum tool to the flush point is ± 310mm. In this test, researchers made a determination where the vacuum tool would be at -157.32mm from point 0 of the Z axis to carry out the watering process at all planting points.

Table 3. is a watering test by measuring the time at each watering point and carried out at 9 flush points.

**Table. 3.** Calculation Data of Watering

| No. | Position | Time (sec) |
|---|---|---|
| 1. | Water tool flushes point A1 | 03.22 |
| 2. | Water tool flushes point A2 | 05.19 |
| 3. | Water tool watering point A3 | 06.67 |
| 4. | Water tool watering point B1 | 05.98 |
| 5. | Water tool watering point B2 | 06.01 |
| 6. | Water tool watering point B3 | 05.75 |
| 7. | Water tool watering point C1 | 06.27 |
| 8. | Water tool watering point C2 | 06.03 |
| 9. | Water tool watering point C3 | 05.99 |
| Total Timing | | 51.11 |
| Average | | 05.67 |

The time taken to complete the watering process is less than 1 minute for 9 planting points at a moderate speed. The time required is very fast. But sometimes the robot is unstable at high speeds. The instability is due to the use of one motor on the X-axis makes the movement less stable at high speeds. movement is less stable at high speeds.

## 6 Conclusion and Recommendation

The real-physical miniature model of home scale farming with a fully automation features including web-based remote management system has been developed in this research and shows a significant improvement in the term of intelligent or robotic-based smart farming. Users can manage their own home-scale gardens from anywhere and anywhere. However, after finishing the (first step) research so far there is an important question, is it possible to expand and extend to a wider area as well as in the form of vertical farming. The using of fully autonomous robot in urban farming seems to be more challenging in the future.

## Acknowledgement

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