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Farming Bot: Precision Agriculture System in Limited Land Based On Computer Numerical Control (CNC)

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Abstract. Indonesia is a vast country both sea and land, but as population development and growth continues to increase, the land that is usually used for agricultural land is now changing into residential land. This narrowing land is the biggest challenge that must be faced today. Basically, farming activities require a knowledge base that is land use, seeds/seedlings, cultivation, processing, to marketing. However, cultivation on land is limited by several methods of land use such as the use of roof gardens need to be considered well because it requires a large investment and careful planning. One way that can be done is through modern technology for energy efficiency and time. In this study, a precision farming system was created using Computer Numerical Control (CNC) technology. CNC is a machine tool automation system that is operated by command, randomly programmed and stored in storage media. By using CNC technology, it allows the machine to follow the coordinate points that are entered into the system accurately. The command to drive a CNC machine is usually called the G-Code. The accuracy of the machine motion using a stepper motor can reach 1 mm. The system is made, similar to the control system on a 3D Printer machine with a wider work area. Later, the machine-made will be named "Farming-BOT", short for Farming Robots or robots for farming..

1.   Introduction

Indonesia is an agrarian country, where most of the population lives in rural areas with a livelihood as farmers. Indonesian people generally consume agricultural products for their daily needs and help in their economy. Agriculture in Indonesia needs to increase production as much as possible to be able to meet national needs, the challenge to achieve this is very large because agricultural areas are increasingly narrowing, climate change, pests, and diseases that attack, the development of other commodities, and technology that is not yet modern [1]. The extent of agriculture in Indonesia which is increasingly narrowing this is the biggest challenge that must be faced today, however, there are ways that can be done to anticipate that is by carrying out development in the agricultural sector. Agricultural development is an effort to manage natural resources that are carried out to ensure long-term agricultural production capacity and improve farmers' welfare through environmentally friendly choices [2].

All agricultural businesses are basically activities that require the same basic knowledge of land use, seed selection, cultivation, processing, packaging, to marketing, but for limited land cultivation or gardening can use several land-use methods such as the use of a roof garden needs to be considered well because it requires a large investment and careful planning. Not all types of plants can grow in a limited area, especially plants that have large stem diameters. Shrubs, shrubs, and flower trees can be alternative gardening objects on limited land. Meanwhile, if we want to garden while growing vegetables, the types of vegetables that can be cultivated are tomatoes, lettuce, spinach, cabbage, beans, and chili.

The use of narrow land, wherever plants can grow, the important thing is there are factors that support the

growth and development of plants such as the presence of sunlight, planting media, fertilizer, and water. One type of plant that can usually be harvested in one month which is around 28-32 days is a type of vegetable plant and all will grow and develop properly if done systematically. Starting from the selection of seedlings, seedlings, irrigation, fertilization or care to harvest.

In this study, a precision farming system was created using Computer Numerical Control (CNC) technology. CNC is a machine tool automation system that is operated by randomly programmed commands and stored on storage media [3]. By using CNC technology, it allows the machine to follow the coordinate points that are entered into the system accurately. The command to drive a CNC machine is usually called the G-Code [4]. The accuracy of the machine motion using a stepper motor can reach 1mm. The system is made, similar to the control system on a 3D Printer machine with a wider work area [5]. Later, the machine-made will be named "Farming-BOT", short for farming robots or robots for farming.

Growing media is made using a mixture of soil and husk. By utilizing CNC technology, plant spacing can be adjusted via a Graphical User Interface (GUI) connected to the machine. This makes it easy for users to plant various types of plant seeds by considering the area of growth. Another feature of Farming- BOT is automatic watering. By utilizing the timing IC, watering can be done periodically and / or when the water content in the soil is detected low. An android application is also made to control Farming- bots manually. The application also comes with a planting period calendar that serves to inform the user, when the harvest will arrive according to the type of plant used. The development of Farming-BOT can be a breakthrough for urbanites who want to farm on limited land and monitoring time. Farming-BOT allows the care of plants from the nursery to the harvest is done automatically.

2.   Research Methods

With the development of industry 4.0, smart farming systems have been created. In 2015 Chetan, et al. make smart farming with automated processing of plants [6]. Patil et al also added sensors integrated with the internet to monitor plant conditions [7]. With the development of CNC technology which is open source, Jauhari applies it to regulate the condition of hydroponic plants so that plant maintenance can be carried out automatically. [8] by commands that are programmed in a structured way and stored on storage media. In traditional CNC systems (computer numerical control) based on ISO 6983, the controller is separated from the CAM module, so that some important information such as 3D geometry, tolerance, and surface roughness information is lost so that information cannot be completely transferred between the CNC system and CAM. To enhance the functionality and expansion of existing CNC interpretation techniques, the new NC programming language model is divided into three modules. Based on the control of the central management module, the modulated CNC interpreter module can call the tool path planning module directly.

In this research, NC technology is implemented to automate the planting process in limited land using land and husks. Automation includes scheduled watering, fertilizing and weeding. In further research, CNC systems are combined with cloud computers so that access to machines can be done on-line. The development of smart farming has several advantages, including making it easy for farmers to monitor crop conditions, facilitate regular and precision crop maintenance, increase crop productivity, and so on. This research method consists of several stages, such as literature review, data collection, parameter identification and data processing, application development, results and discussion, conclusions and recommendations.

2.1. Literature Review

The literature review is carried out to collect information from several references related to the issues to be discussed. Theories related to research problems are used as a basis for processing data. At this stage, identification and problem formulation will be conducted which will be the objectives of the research. Problem formulation to be examined based on the background of the problem.

2.2. System Design

The development of tools is carried out following the latest technology from the results of the Literatur CNC technology development study. FarmingBot consists of 2 main components: an embedded media box and an integrated CNC machine. The planting media box is made of 3mm thick plywood with a length of 150cm x 100cm x 30cm. For CNC machines using stepper motor drive every 2 motors for the X-axis, 1 motor for the Y-axis and 1 motor for the Z-axis. At the end effector of the CNC machine, there are 2 hose connections and 1 humidity sensor. Each hose is connected to a 12 Volt DC pump motor. The first hose serves to flush water and the second hose se ves to spray liquid fertilizer. The humidity sensor is used to measure water content in the soil. Figure 1 is a hardware design from Farming-BOT.

Figure 1. Hardware design

2.3. System Testing

Testing is done by analyzing the results of cropping using Farming-BOT technology. Using Farming-BOT technology, watering and fertilizing plants can be done precisely and measured. The results of planting from farming-BOT are used as analysis material to measure the effectiveness of the use of this technology. In one growing medium given several kinds of plant seeds with a specified spacing.

2.4. Results and Discussion

The results produced by the tool are then compared with the results of expert assessors. The equation that comes out shows the value of accuracy possessed by the tool. The method used by the research is Ground Truth.

2.5. Conclusions And Recommendations

This stage is the final stage of the research that draws conclusions from the results of the analysis of the discussion and provides suggestions for further research. This stage reviews the implementation of related technology/research, this is carried out to ensure that the research has a novelty contribution to the research fields,

3. Result and Discussion

3.1. Hardware Realization

The hardware realization results are shown in figure 2. The stepper motor used for the X and Y-axis movers of type Nema23. Stepper motor for Z-axis type Nema17. All 12 Volt motors are powered by 220VAC to 12 V 15 Ampere DC power supplies. All motors are connected to the TB6600 motor driver. TB6600 motor driver is a stepper motor driver with Serial communication. All three motor drivers are connected to the ATMega328 microcontroller. The controller is also connected to the RTC ds3231 IC for timing via I2C communication. While the humidity sensor is connected to the Analog pin microcontroller. All wiring and laying of hoses are connected through ducting cables which are attached to the sides of the aluminum frame. A 1.3-inch OLED graphic LCD is used as a process status display screen on the Farming-BOT machine. Wiring on the controller is mapped in table 1. Figure 3 is a pin configuration for driving motor control on a Farming-BOT machine. Figure 3b is a system block diagram of a Farming-BOT machine.

Table 1. Microcontroller Pin Mapping

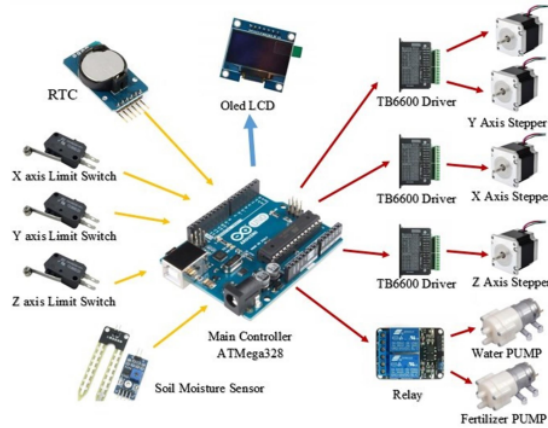| Arduino PIN	Device
2,3	Driver BTS X Axis
4,5	Driver BTS Y Axis
6,7	Driver BTS Z Axis
8	Switch Sensor Home X Axis
9	Switch Sensor Home Y Axis
10	Switch Sensor Home Z Axis
11	Relay for Motor Water PUMP
12	Relay for Pupuk PUMP
A4,A5	Oled LCD, RTC DS1302
A3	Humidity Sensor

Figure 2. Farming-BOT hardware,   **Figure 3**. System block diagram

3.2. Programming

The controller will read sensor data RTC 1302. If the time is right at 08.00 and 14.00 then the controller will do the watering process. The controller will move the stepper motor to the plant location points that have been stored in the controller memory. In this study, spacing was set with a length of 15cm and a width of 10cm. The controller will arrange for delivery on the Y-axis first and then shift on the X-axis.
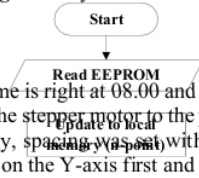
Figure 4 is an illustration of the end effector movement of the Farming BOT machine. The watering distance can be set using the GUI application on the computer. Also, the end effector can also be driven manually through the GUI application to check the water content of the soil. The programming algorithm on the Farming-BOT controller is shown in figure 5.
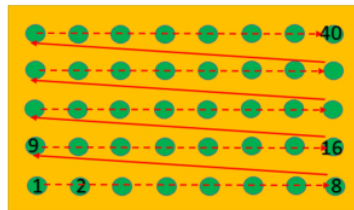

Figure 4. End efector Route

3.3 Crop Yields

Vegetable plants conducted in this study are types of green vegetables (mustard, pakcoy, lettuce), the first stage is to do the seeding first, the nursery is carried out using soil media and charcoal husks in a ratio of 1: 1 and carried out in sausage media (forms such as sausage). Then after the seedlings are 14 days old or the seedlings have as many as 3 to 4 strands, transplanting is carried out. The spacing used is 15 cm x 20 cm. For transplanting, the planting medium used consisted of a mixture of compost and charcoal with a ratio of 1: 1 which was then put into the planting box media with a depth of 20 cm. At the end of the 15 day germination, two seedlings with attached soil were taken from the germination tray for transplanting in the plots with space between plants of 20 cm [9], before the planting box had been given a hole or perforated with a diameter of about 1 cm at some point, where this hole serves for

the exchange/circulation of air and oxygen for plant roots and facilitate the process of entry and exit of water so that plants are not flooded, because it will rot on the roots and plants can die if there is inundation. According to Crawford [10], roots can develop in response to the distribution of nutrients and groundwater. Salisbury and Ross [11] assert that the shape of roots is more influenced by genetic factors than environmental factors, although the environment also determines the formation of its roots. The development of root systems is influenced by the condition of the substrate or soil as a medium for growing plants.
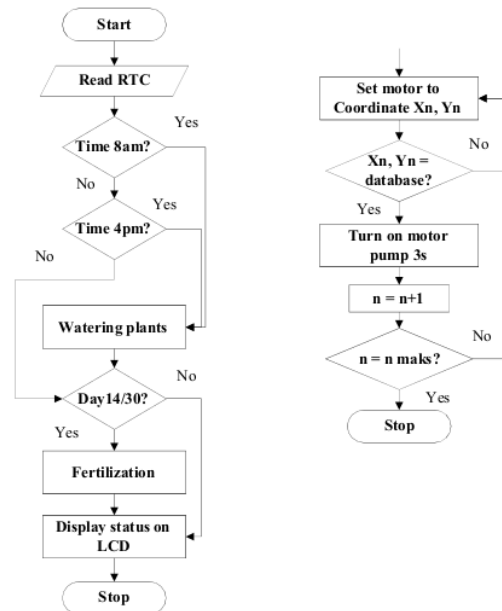

Figure 5. *Flowchart Farming-BOT*

The media used must be porous, lightweight, and have good aeration to support plant growth optimally. Also, planting media must be easily obtained and have an affordable price. The use of compost and husk aims to provide nutrients so that the plants develop well. Nutrients absorbed by vegetable plants are obtained from the soil and fertilizers. Husk charcoal is an organic material which is a planting medium that can maintain moisture. This is because the husk charcoal is more porous because it has almost balanced macro and micropores so that the air circulation produced is quite good and has a high water absorption capacity. The ability of the media to store these nutrients will affect the availability of nutrients in the media. Compost is one of the organic fertilizers used in agriculture to reduce the application of inorganic fertilizers. Compost can improve the physical properties and microbiology of the soil [12]. Compost contains nutrients such as nitrogen and phosphate in the form of argon, protein, and humus complexes, which are very difficult to absorb by plants [13].

After planting, treatment is carried out ie watering and fertilizing. Watering is done automatically using the Farming-BOT system. Fertilizing is given when the plant is 2 MST (Weeks after planting), the fertilizer used is liquid fertilizer containing Nitrogen. Fertilizers are also given automatically using the Farming Boot system. The addition of fertilizer affects the structure of the husk charcoal to be better for root development so that nutrients can be absorbed optimally. Nutrition greatly influences the formation of leaves, especially the element nitrogen (N). According to Hardjowigeno (1995), plants that get enough N elements in the soil will grow greener. Lingga (2005), explained that the element N functions to stimulate growth in the vegetative phase especially leaves and stems. According to Irene Ridge [14] plants can respond in three (3) ways to increase the ability to obtain nutrients, namely by 1) changing the root geometry, relation to root growth, 2) increasing the ability to absorb ions in the soil, and 3) forming associations with other organisms that can help supply nutrients. This is in line with Smith [15]

stating that compost includes solid organic fertilizer which is slow release (releasing nutrients that it contains slowly).

Also, an analysis of the accuracy of the Farming-BOT engine was carried out. The test is carried out providing input of several coordinates at random, and measuring the position of the end-effector at the reallocation. The experimental results are shown in Table 2. The position margin given with the real position has a difference of about 0.8cm. This can be caused by the slip factor in the movement of the stepper motor. However, the value margin is still below 2cm so it can be tolerated for this system. Figure 6 is the result of treating plants using Farming-BOT.
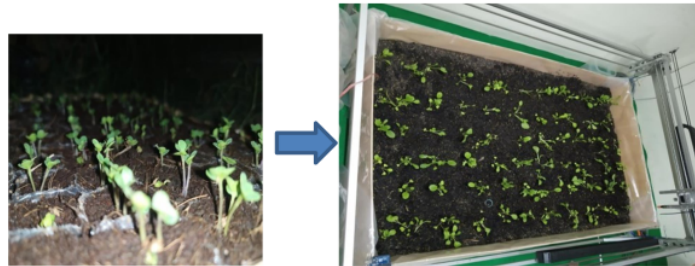

Figure 6. Plant growth

Table 2. Position testing

Y (cm)			X (cm)		
Input	Real	Error	Input	Real	Error
14	14.5	0.5	20	19.2	0.8
50	50.2	0.2	30	30.3	0.3
85	85.6	0.6	64	63.3	0.7
90	89.3	0.7	70	70.2	0.2

Conclusion

Based on the results of research that has been done, for modern technology in terms of crop cultivation of vegetables using Farming bot is very effective and efficient, especially in terms of time and energy because Farming-BOT can work according to the algorithm planted on the controller. Farming-BOT can be used to help plant care until it's ready to harvest. Utilizing CNC technology, the process of watering and fertilizing can be done with a random cropping position. This makes it possible to treat different plants in one media. the results obtained in growth and development also indicate good plant growth. Future research, Farming-BOT will be developed to be able to plant seeds and be monitored on-line through the internet network and in a wide range.

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