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Design and Development of a Control System for Automated Rotary Planting

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Abstract
This research has been done to design and develop a planting system as a need to improve an urban farming technology. This planting system is targeted to cultivate edible crops on urban house or building which can produce food plants within a decorative landscape. The design was inspired by a Ferris wheel which the rotation mechanism is intended to allow enough sunlight and good air flow to each crop in the planter box. This rotation gives chance to each crop in each planter box to sunbathe during sunny day. The rotational mechanism is also aimed to assist all range of consumers to run agricultural activities at convenient height. The system is equipped with sensors and a motor for an automation control. Arduino Uno was used as a microcontroller to control irrigation system and relocation of planter boxes to the various positions. The irrigation system starts it operation at 8.00am and 12.00pm. The rotation of planting system will stop at every 45 degrees until it complete the full rotation for 2 times. The relocation of planter boxes happens at 9.00 am, 10.00am, 11.00am, 1.00pm, 2.00pm and 3.00pm. Each planter box is positioned at the new location to expose to the sunlight for an hour long. Results obtained from the functioning test showed a good and promising performance of the rotary planting system as it can be automatically operated to grow crops in an urban residential.

Keywords: rotary planting system, irrigation, control system, urban farming, microcontroller, arduino, automation

Introduction

The limited space for agriculture activity has boosted an idea to grow plant on stackable pot which is known as vertical farming. This type of farming cultivates crops on the multitier pots which can be installed on the wall or placing them on the floor with numbers of pots stacked on top of other layer (Blatter, 2013; Fell, 2011). In a few recent years, vertical farming becomes one of the most preferred and popular designed of planting system because it can expand the production of fresh food on a very minimal space. One acre for growing plants using vertical type system can be the same as many of ten to twenty on conventional open field-based acres (Despommier, 2011). Instead of planting crops on the spacious land, technology of vertical farming can be adapted in the city since it is less dependent to land, easy to maintain, require minimal distance to travel and at the same time can secure food to the resident (Mustafa Koc et. al, 1999). Limited and expensive water resources in urban area had contributed to an efficient use of water in this type of farming (Smit et. al, 2001). There are many advantages of urban farming to the city communities. It helps every household to grow their own food, educate people for consuming healthy food, create jobs, increase local economic for neighbourhood, and improve communities revitalization (Hagey et. al, 2012;Besthorna, 2013).

Research shows that urban farming is favourable among females and old folks compare to young and adults male (Carola et al, 2017). Thus, the design of the new planting system must takes into account the need of the consumers. The vertical farming itself require a "grow up planting system" where crops are cultivated from bottom to top. For short consumer, the vertical system is often a challenge for them to manage the crops. This is why the rotary planting system is introduced. It is to cater the most targeted consumer of urban agriculture.

The development of rotary planting automation system is planned to offer an ergonomic way to the user for planting crops. It is also give the best solutions to the space constraint. It is targeted for houses or buildings with limited space to cultivate edible crops which can produce food plants within a decorative landscape setting view.

Material and Method

Rotary Planting Structure

The concept of the rotary planting automation system is based on the design of the Ferris wheel as shown in Figure 1. The purpose of rotating mechanism is to ensure all crops in each planter box are exposed to enough sunlight for photosynthesis process. Besides, the rotating system allows the planter box to stop at desired height for easy maintenance and allow user to do planting activities.

The body of planting structure consisted of a couple of four arms to hold four pieces of planter boxes. The planter box holder was designed for easy maintenance and to remain the top of the box facing up. This is to ensure the crops and soil face upward even when the system is rotating 360^{O}.

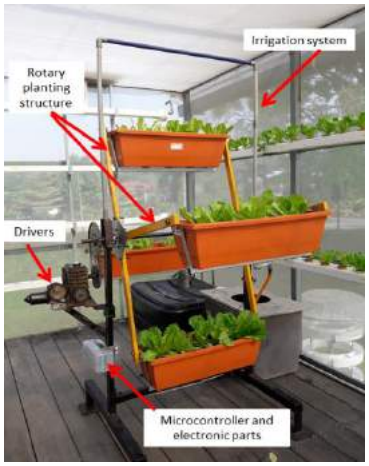

Figure 1: Rotary planting system

Actuator

The system uses DC motor to actuate the rotating arms. The most important criteria in choosing the motor was to estimate the torque required to rotate the planting system. Torque (τ) is an amount of force acting on an object that results in the object rotating. In rotational motion, torque can be described as the multiplication of moment of inertia (I) and angular acceleration (α). The moment of inertia is known as a quantity expressing a body's tendency to resist angular acceleration, which is the total product of the mass of each particle in the body with the square of its distance from the axis of rotation. The torque required by the motor to actuate the system was estimated.

Irrigation system

The rotary planting structure was installed with the irrigation system in order to supply water to the crops. The system comprised of perforated pipe, 100L water tank, water pump, and piping act as water conveyance canal. The 3/4in pipe which is placed on top of the system is fabricated with 9 tiny holes with the diameter of 1mm as shown in Figure 2. The perforated pipe is used to water the crops at a specified time.

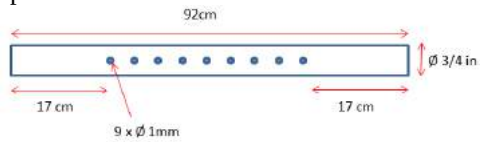

Figure 2: Perforated pipe dimension

Microcontroller

Arduino was chosen as a microcontroller for this project because of it worthy price to run a simple automation instruction. Arduino was preferable over other microcontrollers due to it easy to create program based on open source platform and suitable for many type of sensor's integration.

Rotary Planting Mechanism

In general the operation of rotary planting system can be divided into 2 ways of handling.

i. Manual handling
ii. Automatic handling

i) Manual handling

Manual handling is needed when it is the time of harvesting crops or during crops maintenance. The push button is connected to the circuit as an alternative to bypass the instruction of microcontroller. This is an important feature for the user since every user has different height. They requires different working height to harvest crops thus, the manual button offers a solution for height variety level when operating the system.

ii) Automatic handling

Automatic handling involved two processes
i. Irrigation
ii. Reposition planter box for sunbathing

The design for rotary planting automation system is shown in Figure 3.

Automatic handling requires a Real Time Clock (RTC) to start the process. In this project, RTC is controlled by Arduino Uno microcontroller.

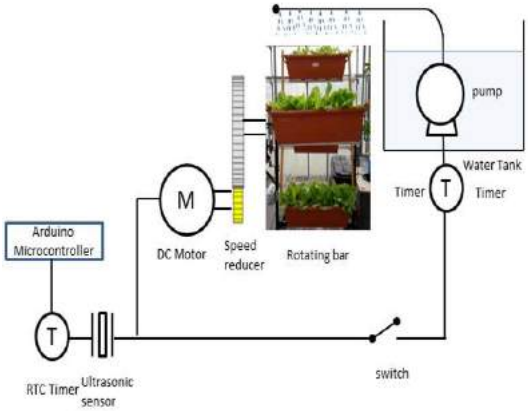

Figure3: Design for Rotary Planting Automation System

Figure 4 shows the flow of rotary planting automation system to operate the system in manual or automatic mode

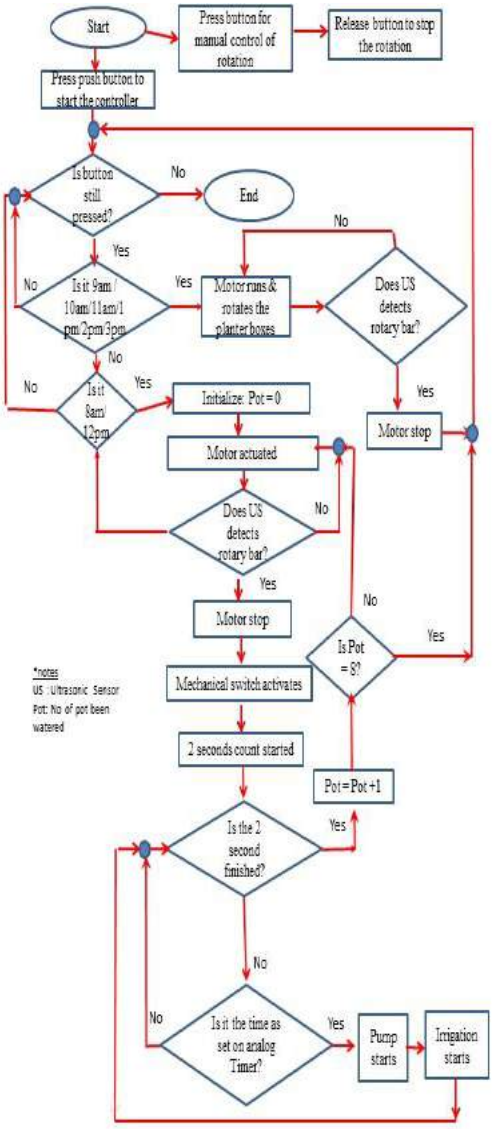

Figure 4: Flow of Rotary Planting Automation System

Results and discussion

Control System Design

i)Irrigation Process

The irrigation system starts it operation at 8.00am and 12.00pm. When the time reached, the system starts and the motor rotates the rotating bar. The rotation will stop at every 45 degrees until it complete the full rotation for 2 times. Ultrasonic sensor is used to stop the motor rotation for 2 seconds at every 45 degrees rotation. During each stop, the pump start and irrigation process run for 2 seconds.

ii) Reposition planter box for sunbathing

The second process of the system is to reposition the planter box. It happens at 9.00 am, 10.00am, 11.00am, 1.00pm, 2.00pm and 3.00pm every day. This process is required in order to expose crops in each planter box to sunlight and to allow good air flowing through the stacking boxes. The reposition of planter box is occurred at every hour where each planter box is positioned at the new location for an hour long.

Sequence of Rotary Planting System

The sequence of Rotary Planting System can be divided into two processes

i. Process flow for Irrigation (RTC timer is set to 8.00am and 12.00pm):

ii. Process flow for reposition planter box (RTC timer is set to 9.00am, 10.00am, 11.00am, 1.00pm, 2.00pm and 3.00pm)

<u>Process Flow for Irrigation (RTC timer is set to 8.00am and 12.00pm):</u>

(1) As the start button is switched on, Arduino microcontroller starts to operate the system

(2) The RTC timer starts the motor when the time set (8.00am & 12.00pm) is reached. The count of variable 'Pot' is initialized to 0

(3) DC Motor rotates in counter clockwise direction to move the rotary bar. It is rotates until the ultrasonic sensor detect the object (rotary bar)

(4) When the ultrasonic sensor triggered, the motor stop, and counting of 'Pot' is started. This means that the first pot is start to given water. The program is coded so that the motor stop for 2 second. When the motor stop, the rotary bar is momentarily presses the mechanical switch which is connected to the pump.

(5) If the time set for the pump set is reached, the pump starts to irrigate the crops when the switch is turned on.

(6) The Arduino controller starts the motor after 2 second and the process start again until the count of variable Pot = 8

<u>Process flow for reposition planter box (RTC timer is set to 9.00am, 10.00am, 11.00am, 1.00pm, 2.00pm and 3.00pm)</u>

(1) As a start button is switched on, Arduino microcontroller starts to operate the system

(2) The RTC timer starts the motor when the time set is reached (9.00am / 10.00am / 11.00am / 1.00pm / 2.00pm / 3.00pm).

(3) DC Motor rotates in counter clockwise direction to move the rotating bar. It is rotates until the ultrasonic sensor detect the object (rotary bar)

(4) When the ultrasonic sensor triggered, the motor stop and the rotary bar presses the mechanical switch.

(5) The timer for the pump is not set at these hour, thus no irrigation happened at this time although the switch to the pump is connected. The off timer cut the connection of the switch and the water pump.
(6) The Arduino controller stops the motor and the process will start again to reposition next planter box after 1 hour.

Conclusion

Results in the field testing shows a good and promising performance of the rotary planting system as it can be automatically operated to grow crops in an urban residential. The planting system is aimed for the constraint space, and natural resources. This system is inspired by a Ferris wheel where the rotation mechanism is intended to allow enough sunlight and air flow to each crops in the planter box. The rotational mechanism is also aimed to assist all range of consumer to run agricultural activities at a convenient height.

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