Vertical Farm Automatic X-Y Table

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***Abstract*— Vertical farms help feed the growing global population and undo the environmental damage caused by conventional agriculture [1]. While there are many benefits from vertical farming, it is vital to ensure that vertical farms enable food production in a safe, efficient, and clean way. The Engineering Technology building (Still Gym) at Northern Illinois University holds a vertical farm in their BEEEAM (Building, Energy, Efficiency, Ergonomics, and Management) Lab. To ensure that each plant at the NIU vertical farm is healthy, a Raspberry Pi controlled X-Y positioning table will be integrated within the existing vertical farm. The X-Y table will have the ability to traverse the 2ft by 4ft area (growing tub area) using belt-driven movement. The table will contain specific sensors used to collect data from microgreens grown.**

I. Introduction

Vertical farming is experiencing a growth in interest due to many factors including the reduction of useable agricultural space and the ability to set up farms in smaller areas. In the NIU BEEAM Lab, the vertical farm grow tables have seen many advancements in recent years, however, due to COVID-19, some of the processes were automated [1]. It was determined that automated measuring and scanning capabilities were also needed.

Impacts of an Automated measuring system

Having an automated system in place will allow the user to run scans with a wide variety of cameras and sensors across the entire table. Right now, these scans are being done by hand. The goal of automation is to run scans along with the lighting cycles, which are already automated.

II. Components and Functions

Device Functions

The XY table will have two primary modes. The main use will be a continuous scan on a pre-determined path across the grow tubs below. The other will be a point scan, where the user will input a specific point and the table will move to that location.

Electrical Components

- NEMA 17 Stepper Motor
- TB6560 3A Motor Controller
- 1.4 GHz 63-bit quad core Raspberry Pi 3B+
- Hinge Roller Lever Micro Switches 3 Pins
- Plastic Enclosure

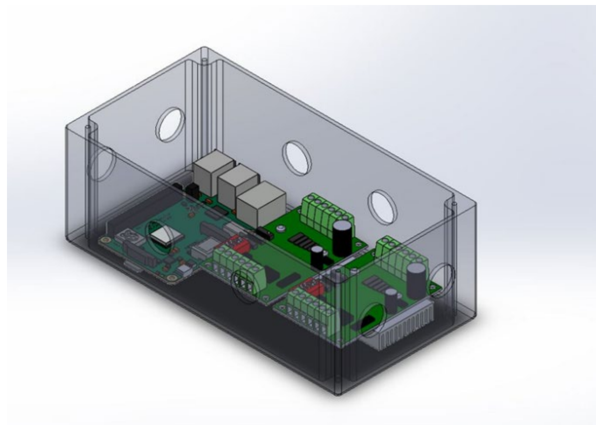

Figure 1 Enclosure with Raspberry Pi and motor Controllers

The image above is a representation of what the enclosure would look like with the Raspberry Pi (RPi) and stepper motor controllers inside of it. The RPi will send a signal to the motor controllers using the GPIO pins. This will enable the controllers to send the appropriate amperage to the stepper motors to move the table. Figure 2 below outlines the wiring of the electrical components.

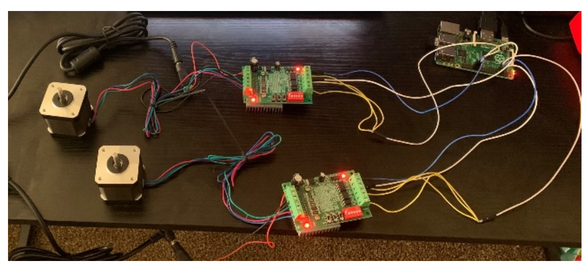

Figure 2 Wiring of electrical components

Structural Components

- 8020 Aluminum Extrude
- Sleeve Bearing
- Timing Belt
- Sensor Mount

The table was designed using the H-bot belt design [3]. Using the single belt approach reduced the footprint of the moving components because both motors were fixed on the ends of the suspended rails. A rendering of this can be seen in figure 3.

Figure 3 XY table with belt and rack mounts

III.

IV. Metrics and Equations

For the table to move properly, the minimum torque required was calculated using equations from Oriental Motor. These calculations are seen here:

Torque Calculations [2]

$$T_L = \frac{F}{2\pi\eta} \times \frac{\pi D}{i} = \frac{FD}{2\eta i}$$

$$T_L = \frac{31.392N * 0.162m}{2 * 0.93 * 1}$$

$$T_L = 0.273Nm$$

η = efficiency of belt
μ = Coefficient of friction
i = gear ratio
F = Force
F_A = Applied Force
D = Diameter of pulley
T_L = Torque load
m = Mass of moving parts
g = Gravity

$$F = F_A + mg(sin\theta + \mu cos\theta)$$

$$F = 0N + 10kg * 9.81m/s^2(sin0 + 0.32cos0)$$

$$F = 31.392N$$

Results

From these calculations, the motor selected was the NEMA 17 Stepper Motor. The specific motor chosen is 0.44 N*m each. Having two motors to move one belt nets a total torque applied of 0.88 N*m, roughly 3 times the minimum torque required. The motor takes 400 steps to complete one revolution (0.9° step angle). The circumference of each pulley is 50.89mm, or about 2 inches. Each step will move the table approximately 1/200 inches. This will keep the table accurate and ensure repeatability when carrying the various sensors.

V. Conclusions

Creating an easy to assemble XY table will allow the BEEAM Lab vertical farm to add in automated sensing and scanning of the plants. The exact sensors being used are currently being researched by another team. Future improvements identified include adding various safety features. These include end caps on the end of the extruded aluminum. Also, there is potential to flip the assembly to point up, and with proper code adjustments and a z-axis, the table can act as a goniophotometer to measure the lighting in the system at any point within the grow tubs in the farm [4].

Figures

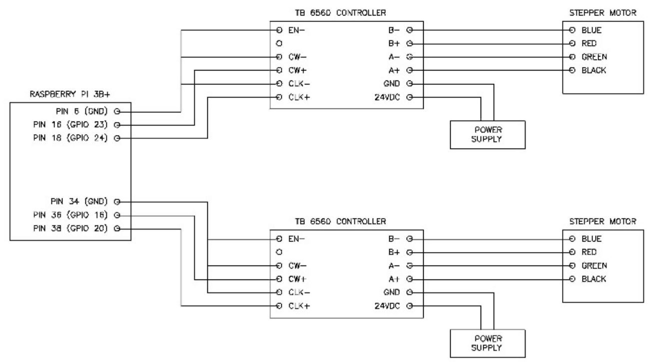

Figure 4 Wiring Schematic

Acknowledgments

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References

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[4] Merriam-Webster. (n.d.). Goniophotometer. In Merriam-Webster.com dictionary. Retrieved April 7, 2021, from https://www.merriam-webster.com/dictionary/goniophotometer

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