18-500 Capstone Abstract: MiGroBox
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**Scope:**

The goal of this project is to automate a large portion of the process of growing microgreens. Microgreens are essentially young sprouts of various common vegetables, such as radish and broccoli. These seedlings are significantly more flavorful and contain roughly 4 to 40 times as much nutritional value, weight for weight, compared to their fully grown alternatives. The quality of this kind of produce has spurred rapidly-growing popularity and demand from restaurants as well as health-conscious consumers.

The industry, however, has been plagued with several problems. Firstly, cultivating microgreens is incredibly labor-intensive. The weekly growth cycle of microgreens, combined with a low food yield to space ratio, means that growers must constantly dump out spent growth medium to replant new seedlings. Harvesting the plants by hand without getting them dirty also proves a challenge. On top of this, the process is highly detail-oriented. To achieve consistent quality and high yields, growers must carefully monitor their crops and adjust their surroundings to best match the various climate preferences of each plant species. Air circulation and humidity control are absolutely vital in the constant battle to avoid mold - a common failure point that can wipe out an entire crop cycle. Being very tender, harvested microgreens must be kept very dry and cool to achieve even a one-week shelf life. All of these factors mean that a lot of human time and effort is required to successfully cultivate this type of produce. This fact makes it a ripe target for automation.

This capstone project will feature the design, construction, and real-time testing of a countertop CNC grow chamber which partially automates microgreens cultivation. The device will include a number of environmental sensors to actively monitor and adjust its internal climate according to the growth profiles of the specific plants within. It will also feature seed storage, dispensing, and planting.

**Requirements:**

- 50% reduction in labor time
  - Based on prior growing experience, one 1020 tray takes roughly 5-6 hours of human labor to set up, maintain, harvest, and package.
  - The MiGroBox project will aim to reduce this by at least half by removing the time involved in seeding and caring for the plants as they grow throughout the week.
  - The project will involve growing trays of microgreens manually to act as a control to those being grown within the MiGroBox. Careful tracking of time allocated to each batch will determine time saved via automation.
- Dimensions to fit at least one 1020 tray of microgreens
- WiFi connection to a custom website interface
- Power supply capable of running several Nema 17 stepper motors, sensors, fans, and water pumps simultaneously

One of the key challenges lies in the testing routine of the device. Even the fastest-growing microgreens take roughly a week to become harvestable. Thus establishing a constant supply of microgreens to test on will prove vital to keep the project on pace. Several 1020 trays of microgreens will be grown by hand in a staggered manner (for example two started at the start of a week and another two a half week later).

Another serious challenge in this project is the wide range of various sensors and actuators that must all be integrated into the system architecture. Managing such a wide array of inputs and outputs in real time will require a very robust embedded system infrastructure and communication scheme.

**Implementation:**

The core framework of the MiGroBox will be built out of 8020 aluminum with 3D printed parts made of PETG. The CNC will use Nema 17 stepper motors controlled with a custom-made driver motherboard. The stepper motor drivers have not been chosen yet but will likely be either the common a4988's or the more up-to-date and advanced tmc2208's or tmc2209's. The device will likely be controlled via an ESP32 microcontroller running an RTOS with a ported version of the GRBL CNC firmware and custom control software developed over top. We are not yet sure what RTOS we will use, but it will likely be FreeRTOS. The machine will be powered from a wall outlet using a not-yet-chosen power supply. Given the use of roughly 3-6 motors (each consuming 1-1.5 amps) as well as other sensing hardware consuming on the order of 3 additional amps, the entire machine will require a power supply capable of distributing upwards of 12-15 amps at peak usage.

Overall, the system will be designed to be capable of receiving multiple analog and digital inputs from sensors, outputting digital and pwm control signals to stepper motor drivers, lights, and water pumps, and connecting to a website interface. The website will be able to read the sensor values, control the actuators, and store information about the crop species. It will use HTTP requests to communicate with the device, and it will be written in Django. The project will explore distributing control of sensors and actuators from the core microcontroller to smaller ones (such as Attny85's) via I2C.

**Minimum Viable Product (MVP):**

Our MVP will be a wall outlet powered device capable of sensing and adjusting temperature, humidity, and water levels within its grow chamber. The device will have a control board capable of supplying pwm signals to fans and control signals to stepper motor drivers. The MVP MiGroBox will house one 1020 tray of microgreens and will provide automated watering, lighting, temperature control, humidity control, and air flow optimised to the growth regime preferences of several different microgreen plant species. The device will be controlled through a website interface via WiFi.