



**Northern Illinois  
University**

**Open-Source Controlled Environment  
Agriculture Including Development of Water  
Quality System**

# Overview



- Executive Summary
- Current State
- Design Objectives
- Project Details
- Acknowledgements
- References

# Executive Summary



- We are developing/optimizing an automated microgreen vertical farm system.
- The design focuses on lighting controls, climate conditions, and water quality system.



**Radish**

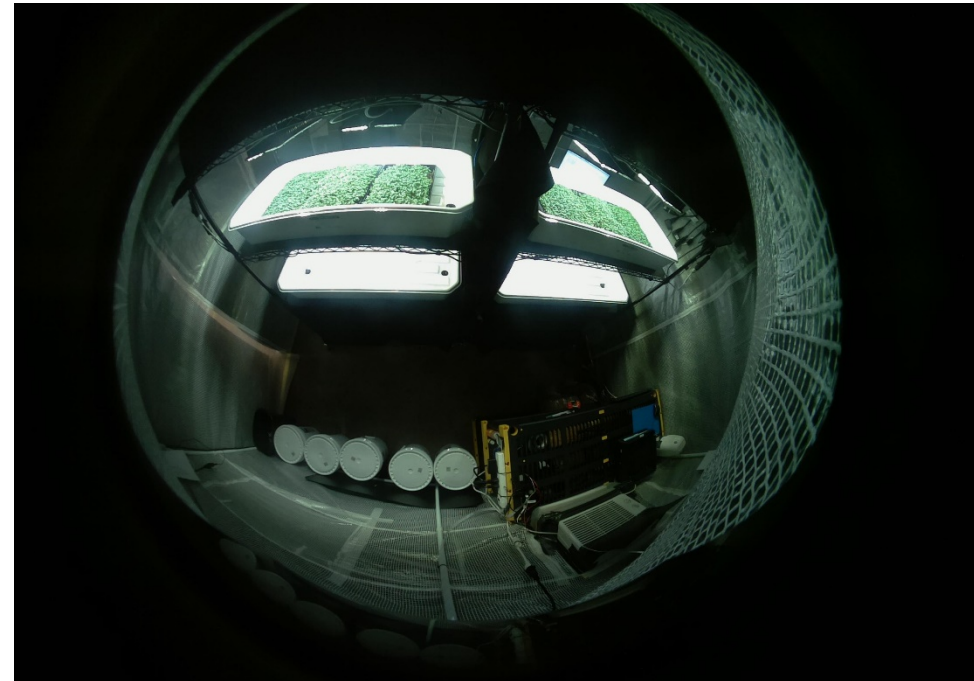


**Broccoli**

# The Vertical Farm



Outside the tent

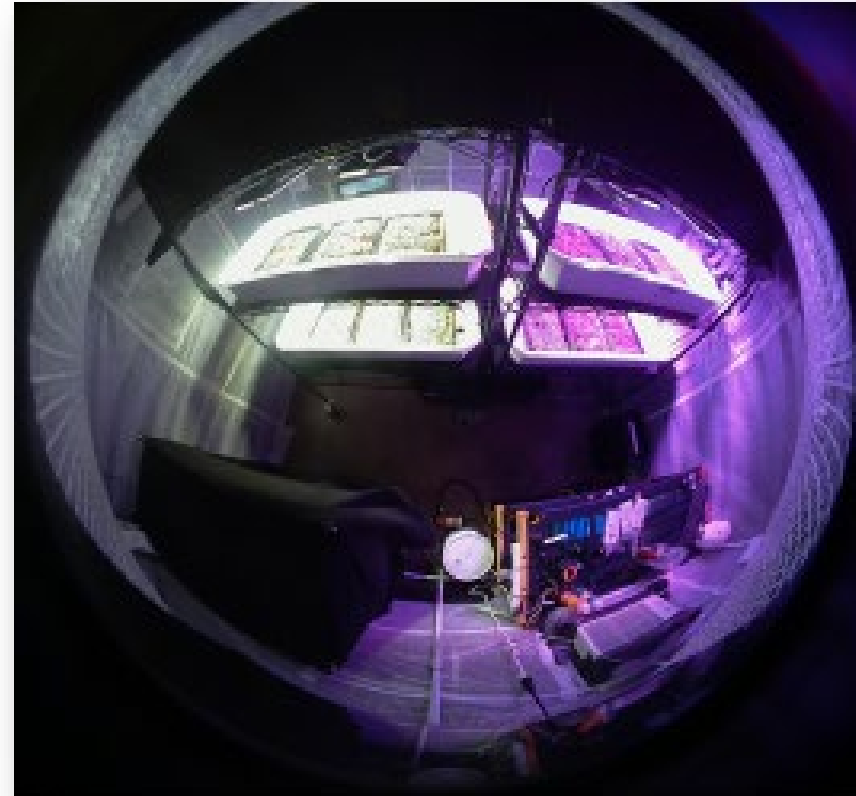


View of farms

# The Vertical Farm



Internal View



During Growth Cycle

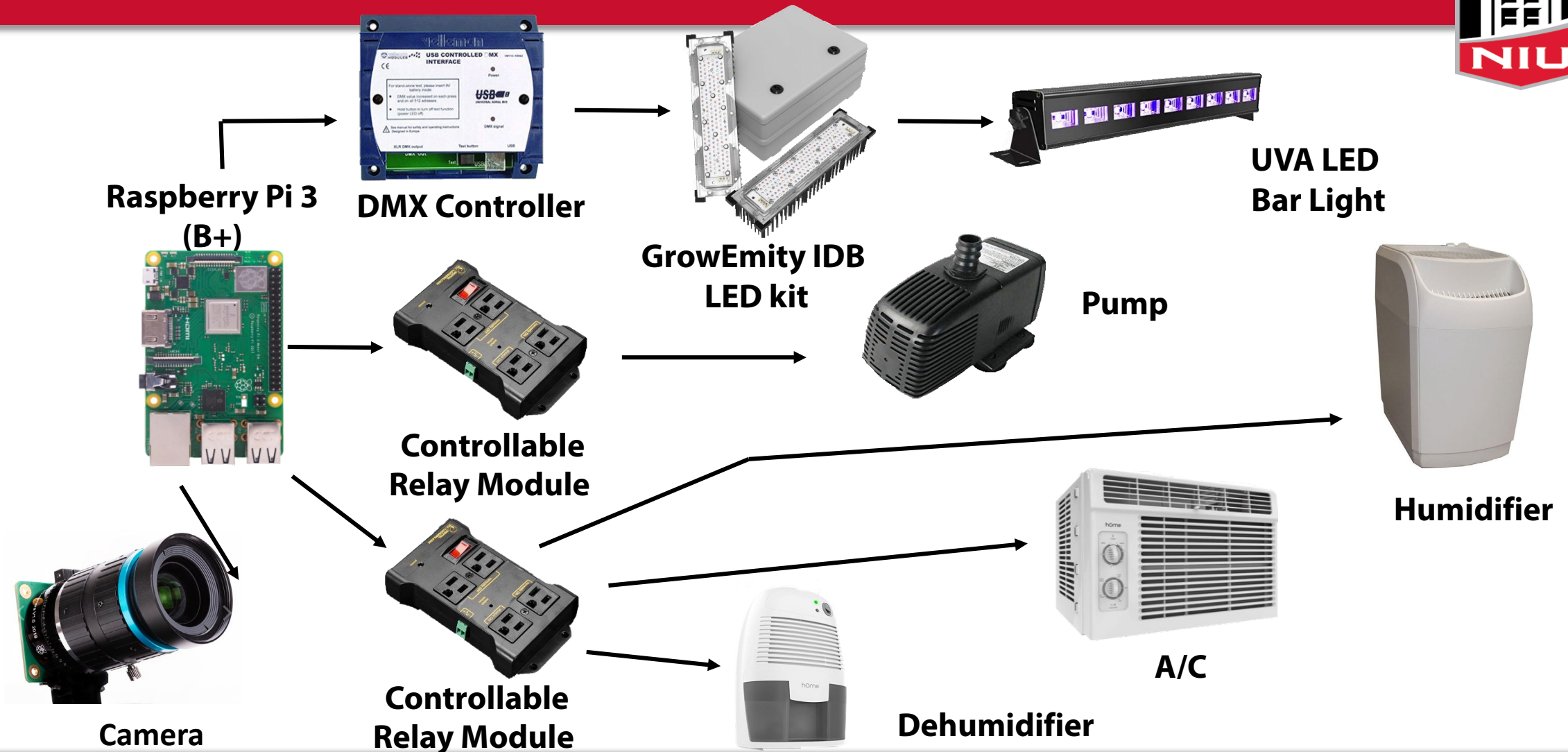
# Design Objectives



- A user-friendly lighting and watering control system
- Improvement of the automated environmental control system for growing microgreens
- Improvement of a feedback-controlled water quality and quality correction system
- Design of Experiments to characterize the light inputs to plant growth outputs to optimize plant yields



# Control System Overview



# Control System Overview (Sensors)



**Ultrasonic Sonar  
Distance Sensor**



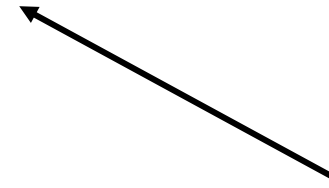
**CM0124 CO<sub>2</sub>  
Sensor**



**CM0187 CO<sub>2</sub>  
Sensor**



**DHT22  
Temp/Humidity  
Sensor**

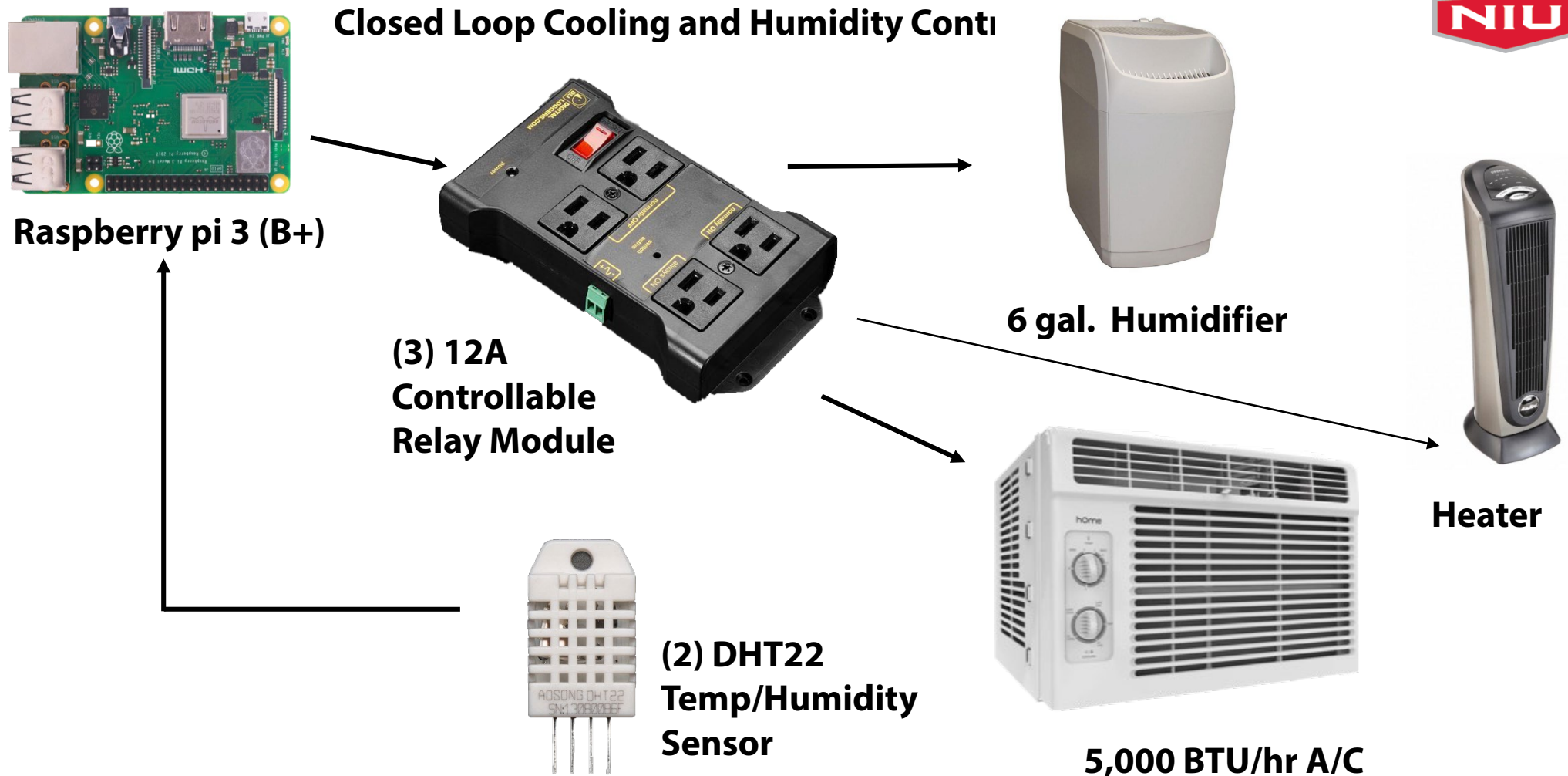






# **ENVIRONMENTAL SYSTEM**

# Climate Control Sub-System



# Maintaining the Optimum Temperature



```
TURNING HEATER ON!! INCREASING THE ROOM TEMP
Temp=27.6
TURNING HEATER ON!! INCREASING THE ROOM TEMP
Temp=27.7
TURNING HEATER ON!! INCREASING THE ROOM TEMP
Temp=27.8
TURNING HEATER ON!! INCREASING THE ROOM TEMP
Temp=27.9
TURNING HEATER ON!! INCREASING THE ROOM TEMP
Temp=28.0
Temp=28.0
Temp=28.1
Temp is at Optimum Temperature
Temp=28.2
Temp is at Optimum Temperature
Temp=28.2
Temp is at Optimum Temperature
Temp=28.3
Temp is at Optimum Temperature
Temp=28.3
Temp is at Optimum Temperature
Temp=28.3
Temp is at Optimum Temperature
```



# LIGHTING

# Light Control Sub-System



**Raspberry Pi 3 (B+)**



**Vellman USB  
Controlled  
DMX Interface(1)**



**Max 465W GrowEmity IDB  
LED kit (8)**



**Max 27W UV LED  
Bar Light (4)**



# Lighting GUI



Vertical Farm Lighting Controls

### Farm 1 Lighting Setup

Step 1		0											
Step 2	Far Red	<input type="range"/>											
Step 3		0	25	50	75	100	125	150	175	200	225	250	
Step 4		0											
Step 5	Deep Blue	<input type="range"/>											
Step 6		0	25	50	75	100	125	150	175	200	225	250	
Step 7		0											
	True Green	<input type="range"/>											
		0	25	50	75	100	125	150	175	200	225	250	
		0											
	5K White	<input type="range"/>											
		0	25	50	75	100	125	150	175	200	225	250	
		0											
	Hyper Red	<input type="range"/>											
		0	25	50	75	100	125	150	175	200	225	250	
		0											
	True Blue	<input type="range"/>											
		0	25	50	75	100	125	150	175	200	225	250	
		0											
	Amber	<input type="range"/>											
		0	25	50	75	100	125	150	175	200	225	250	
		0											
	True Red	<input type="range"/>											
		0	25	50	75	100	125	150	175	200	225	250	

Submit

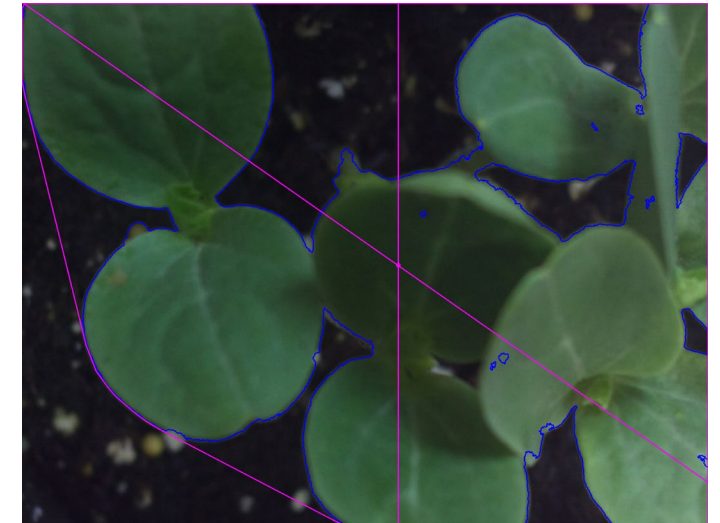
Grow Length, Start Time and Start Date

Step 1		
Step 2	Grow Cycle Length (Days):	<input type="text" value="0"/>
Step 3	Enter Start Date (mm/dd/yyyy):	<input type="text"/>
Step 4	Select Start Time (hh:mm):	<input type="text" value=""/> : <input type="text" value=""/>
Step 5		
Step 6		
Step 7		

# Computer Vision - PlantCV



- Touchless data gathering
- Leaf Area Index



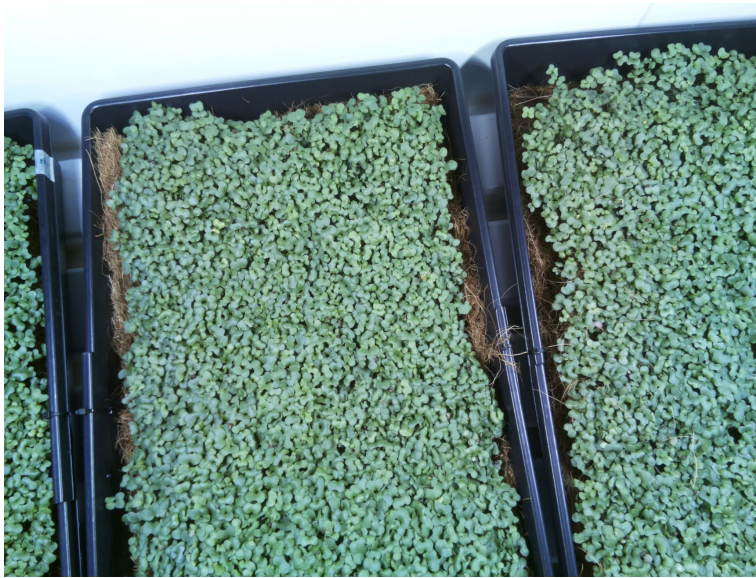


# Computer Vision - PlantCV

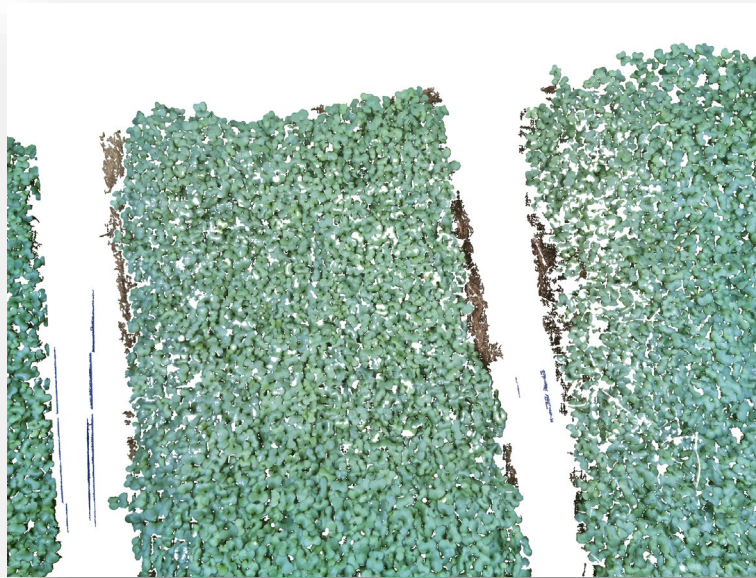




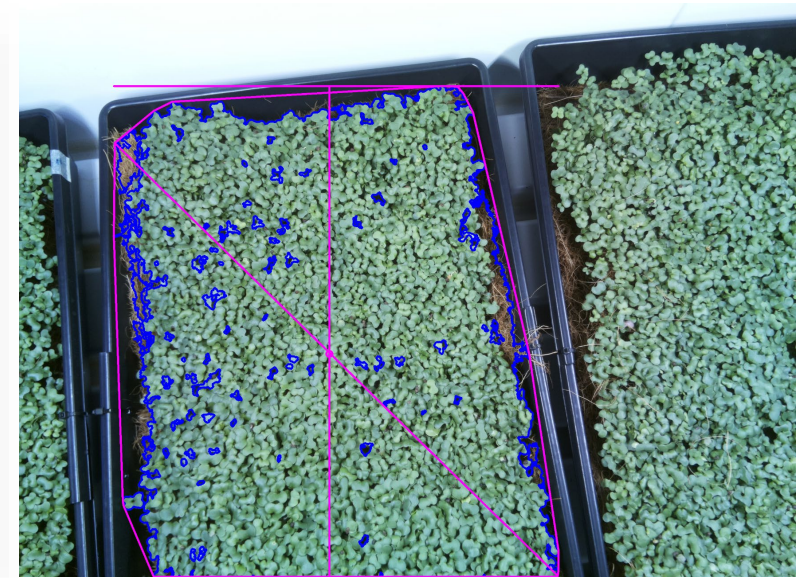
# Computer Vision - PlantCV



Input Image



Background removed



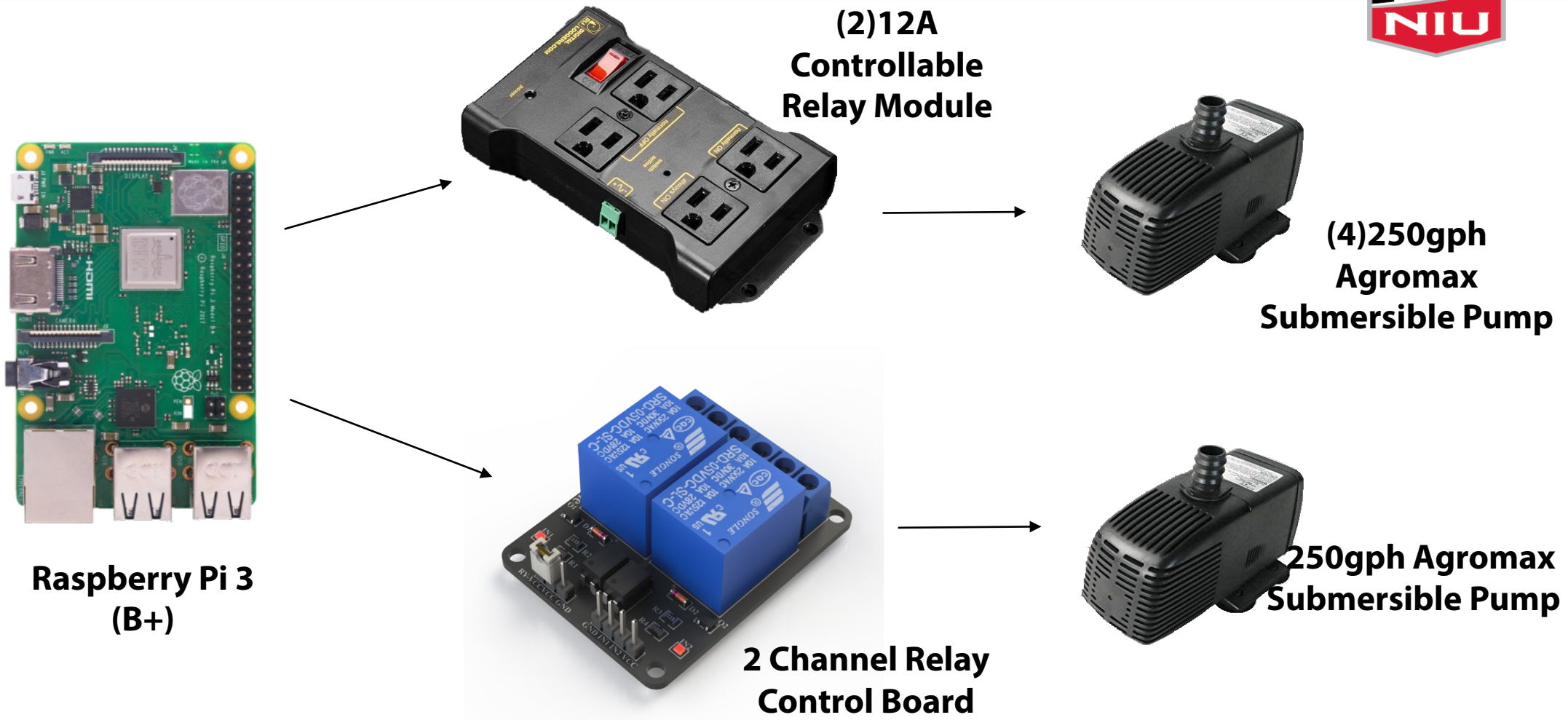
Area of interest captured



# **IRRIGATION SYSTEM**



# Germination/Irrigation Sub-System

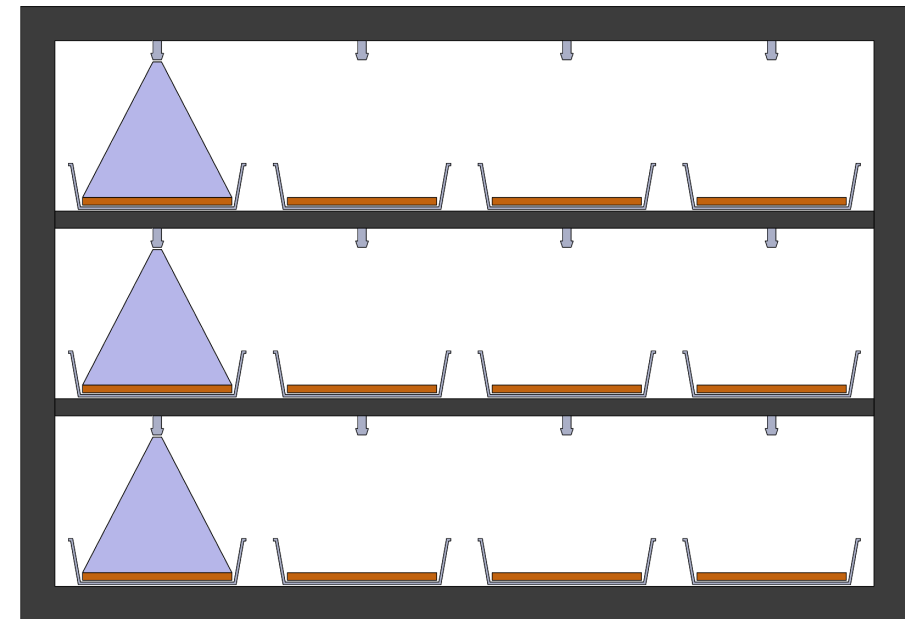


# Automatic Germination Sprayer System



## Design implementation

- Tray mounts
- Misting sprayers
- Control relay
- Misting automation program



# Hydroponic System – GUI



## Water Control System

### Current Setup

Start Date: 11/10/2020  
Length (days): 14  
Occurrences: Twice  
Mode: Germ  
Water Cycle Start Time: 08:00  
Duration (seconds): 60

New Setup

Live Adjustment

Exit

## New Setup

Grow Cycle Length (Days):

Start Date (mm/dd/yyyy):

Occurrences: ☒ Once ☒ Twice

Start Time:

Mode: ☒ Farm ☒ Germination

Duration(seconds):

Submit

# Hydroponic System



- Water quality system implement to reduce:
  - Electrical conductivity (300-400mV)
  - Dissolved oxygen (4-5 mg/L)
  - pH levels (5.5-6.5)
  - Temperature (70-80°F)



# Hydroponic System - Additions





# Water Quality Sensor Readings :



- DATA IS RECORDED INTO A CSV FILE

A screenshot of a terminal window on a Raspberry Pi. The window title is 'pi@raspberrypi: ~/D0'. The terminal shows a series of sensor readings being logged into a CSV file. The data includes timestamps, EC (Electrical Conductivity), RTD (Resistance Temperature Detector), DO (Dissolved Oxygen), ORP (Oxidation-Reduction Potential), and pH. The readings are as follows:

```
File Edit Tabs Help
Timestamp : 2021-03-30 12:34:51.128777
EC 100: 749.6
Timestamp : 2021-03-30 12:34:51.135044
RTD 102: 22.004
Timestamp : 2021-03-30 12:34:56.148892
DO 97: 6.69
Timestamp : 2021-03-30 12:34:56.156714
ORP 98: 210.5
Timestamp : 2021-03-30 12:34:56.162815
pH 99: 7.693
Timestamp : 2021-03-30 12:34:56.169112
EC 100: 750.1
Timestamp : 2021-03-30 12:34:56.175541
RTD 102: 22.008
Timestamp : 2021-03-30 12:35:01.189659
DO 97: 6.63
Timestamp : 2021-03-30 12:35:01.195012
ORP 98: 210.5
Timestamp : 2021-03-30 12:35:01.200360
pH 99: 7.691
Timestamp : 2021-03-30 12:35:01.205949
EC 100: 749.3
Timestamp : 2021-03-30 12:35:01.211709
RTD 102: 22.008
Timestamp : 2021-03-30 12:35:06.225359
DO 97: 6.57
Timestamp : 2021-03-30 12:35:06.231027
```

# Acknowledgements



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  - Department of Engineering Technology
  - NIU College of Engineering and Engineering Technology

# References



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