Aquaponics: Deep Water Culture Systems

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Overview

- In collaboration with Pure Reason AI, we constructed a classification model to identify nutritional deficiencies in lettuce
- Designed and trained convolutional neural networks
    - Using Python libraries Tensorflow and Keras
    - Fully nutritious (FN) or deficient in nitrogen (N), phosphorus (P), or potassium (K)

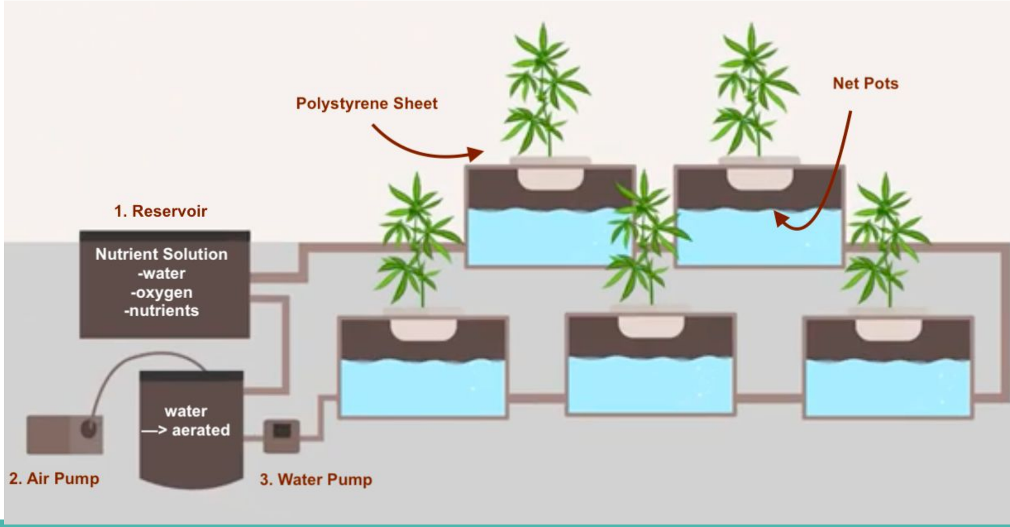
Deep Water Culture

Hydroponic system: Soil-less agricultural system

Deep Water Culture (DWC): Hydroponic system where the root of the plant is submerged in an oxygenated, nutrient-rich water solution <u>continuously</u>

- Most efficient and simple system
  - ➔ 2-3x faster growth rate
    - ◆ More robust root formation
  - ➔ More water = more stable nutrient solution
    - ◆ Less monitoring
  - ➔ Basic structure
    - ◆ Less maintenance

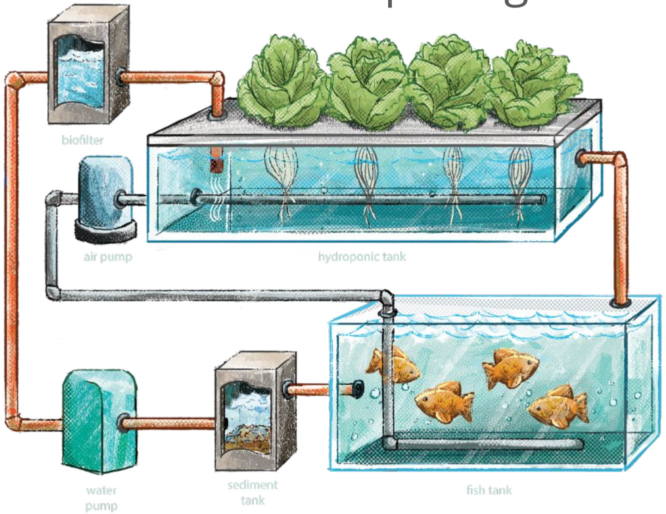
- Adjust the nutrient levels in the solution
  - ➔ To maximize the quantity of nutritious plants per cycle



1. "Deep Water Culture (DWC): What Is It And How To Get Started."
8. "Implementation of an Indoor Deep Water Culture Farming System Using IoT | IEEE Conference Publication | IEEE Xplore"
10. Petrazzini et al., "Nutritional Deficiency in Crisphead Lettuce Grown in Hydroponics

DWC Aquaponic System

- **Aquaponics:** combination of aquaculture and hydroponics
- Our collaborators are developing a **DWC aquaponic system**
  - Nutrients from fish aid plant growth



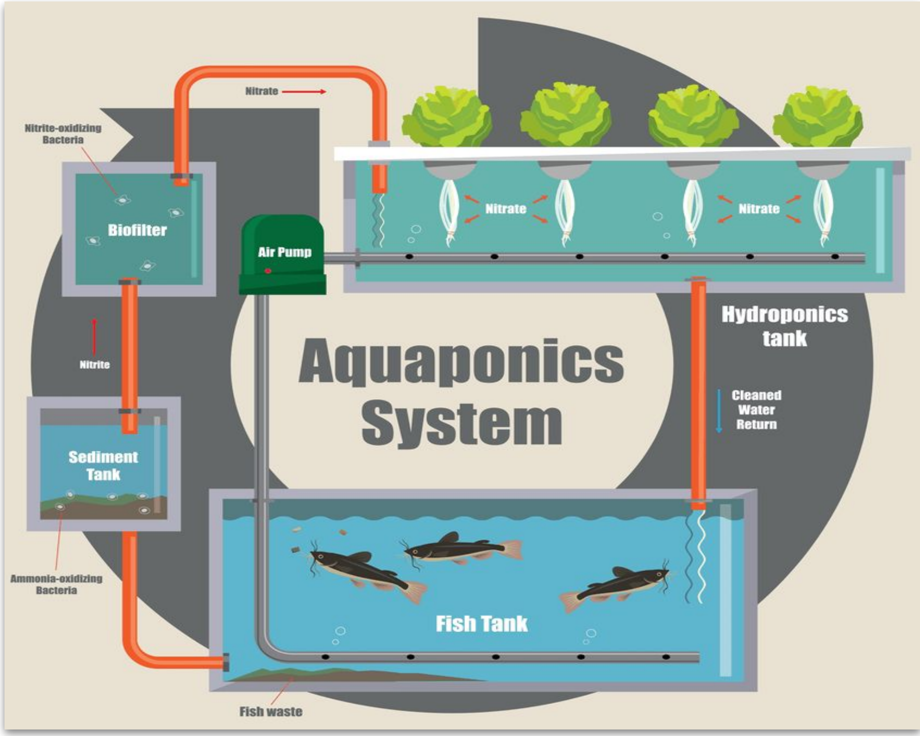
- Plants and fish must have similar temperature/ pH level needs
  - Catfish, bass, and tilapia are among the best to grow lettuce

	Temperature	pH Level
Lettuce	70-74°	5.8-6.2
Catfish	74-80°	5.5-7.0

5. Goddek et al., "Challenges of Sustainable and Commercial Aquaponics"
12. Rocha et al., "LETTUCE PRODUCTION IN AQUAPONIC AND BIOFLOC SYSTEMS WITH SILVER CATFISH Rhamdia Quelen"
11."Recirculating Aquaculture Tank Production Systems"

DWC Aquaponic System Process

1. Fish release nitrogen waste from their gills
   - In the form of ammonia
2. Water feeds into a sedimentation tank & biofilter
   - Sedimentation tank: removes solid waste
   - Biofilter: Beneficial bacteria performs nitrification
3. Water pumped into DWC tanks
4. Plants absorb the nitrate within the water
   - Preferred form of nitrogen when growing higher yields
5. Water becomes purified and re-circulates into the fish tank



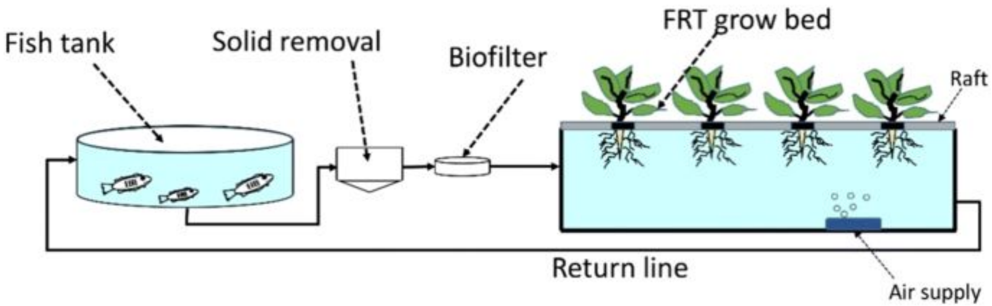
DWC Aquaponic System Pros and Cons

Advantages:

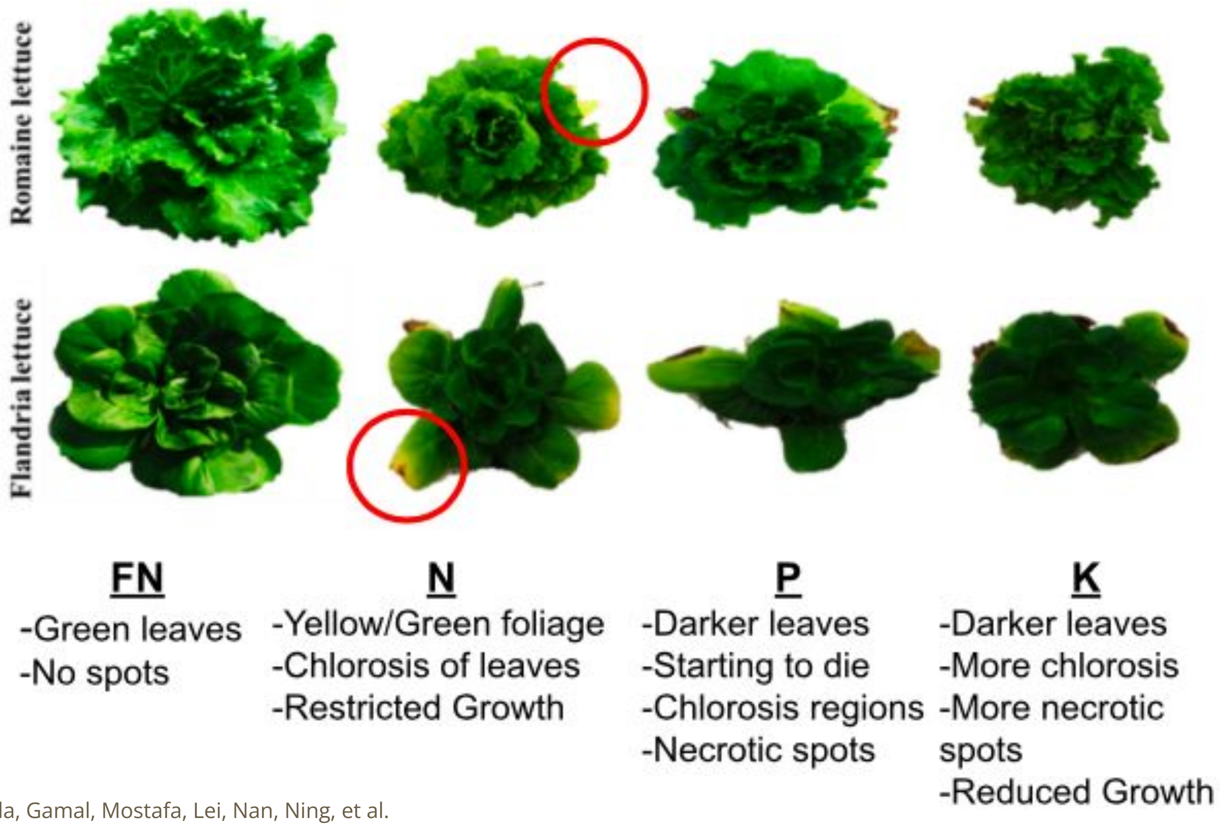
- Water-efficient
  - 90-99% less water
- No additional nutrient costs
  - Fish feed is the primary source of nutrient
- Eliminates soil-borne diseases
- Plants can survive up to 2 weeks w/o power
- 11% cheaper electric cost

Disadvantages:

- Limited to small rooted plants
  - Leafy greens, lettuce, basil
- Higher Start-up/ maintenance cost
  - Due to filtration system



Identifying Nutritional Deficiencies



6. Taha, Alwaseela, Gamal, Mostafa, Lei, Nan, Ning, et al.

Machine Learning Techniques

- Many projects have used machine learning techniques to help detect nutrient deficiencies in plants grown hydroponically
- The use of Convolutional Neural Networks have proven successful in detecting deficiencies by image classification of the plants
- Two projects have utilized CNN's to detect nutrient deficiencies:

Basil Plants:

1. **Used heat images**
2. **89.54% accuracy**
3. **Challenges included wrongful detection and problems with shade and light in the images**

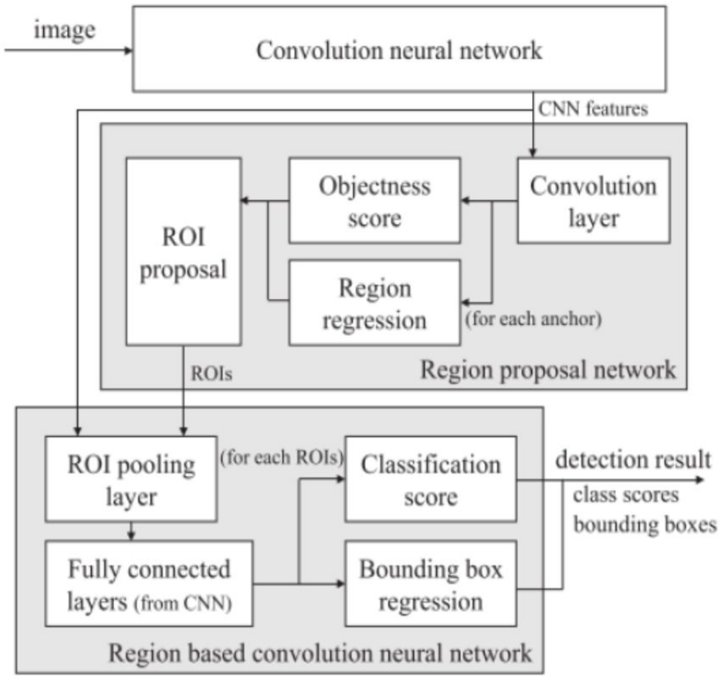
Lettuce Plants:

1. **Used a dataset of images**
2. **Two algorithms ran**
3. **Did not test accuracy of image classification and more work needed to be of practical use**

3. Gul and Sebnem
7. Yudha, Ichsan, Abdi, and Mudrik

Machine Learning Techniques Applied to Our Project

- Using similar ideas to the projects on the previous slide, our goal was to create a system to classify images of different lettuce plants
- Our project utilized CNN's and a collection of datasets to classify images based on the nutrient defincines found in the image



3. Gul and Sebnem
7. Yudha, Ichsan, Abdi, and Mudrik

Project Dataset

- Given to us by collaborators to train with
- Originally contained 300+ pictures
- Removed all corrupted images

Non-corrupted image

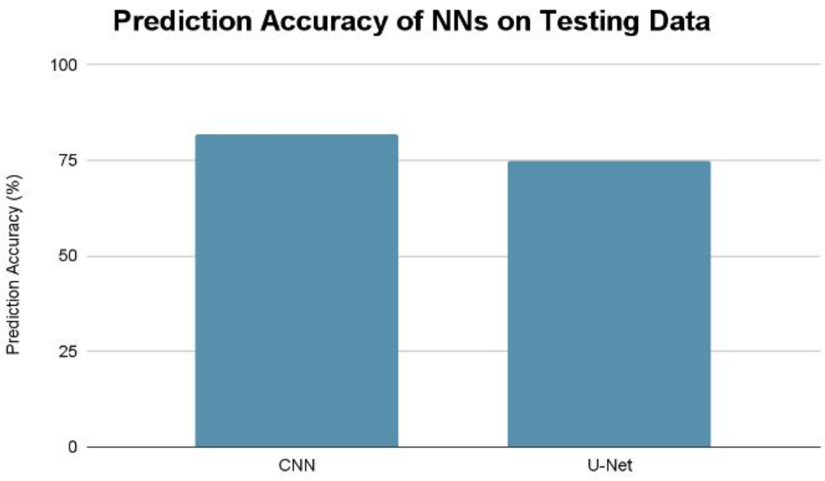
Corrupted image

Finished Dataset

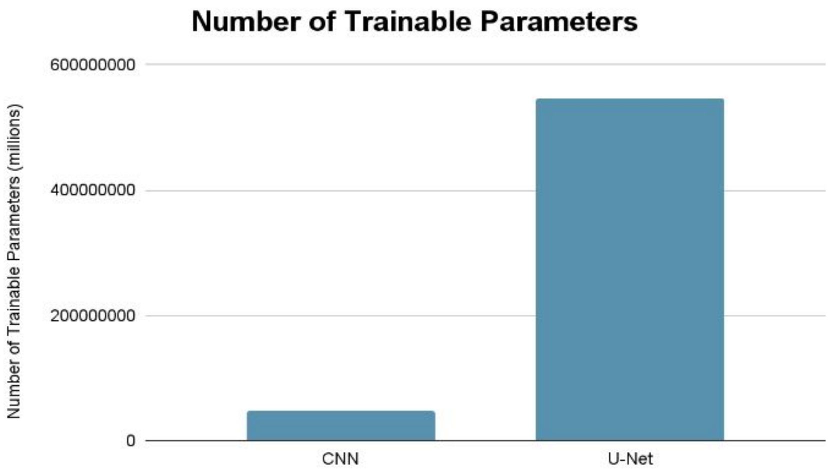
Category	# of Images
FN	12
-K	72
-N	58
-P	66

Total: 208 images

Results



Prediction Accuracy of NNs on Testing Data
Prediction Accuracy (%)
100
75
50
25
0
CNN
U-Net



Number of Trainable Parameters
Number of Trainable Parameters (millions)
600000000
400000000
200000000
0
CNN
U-Net

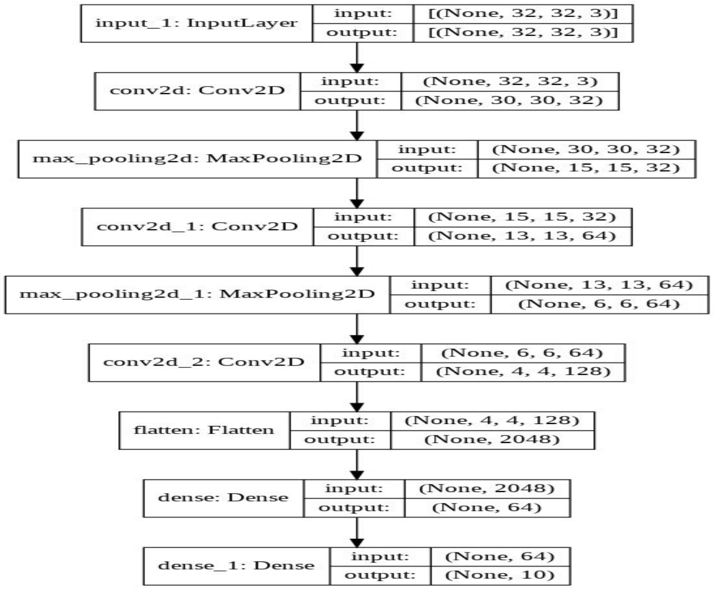
Code

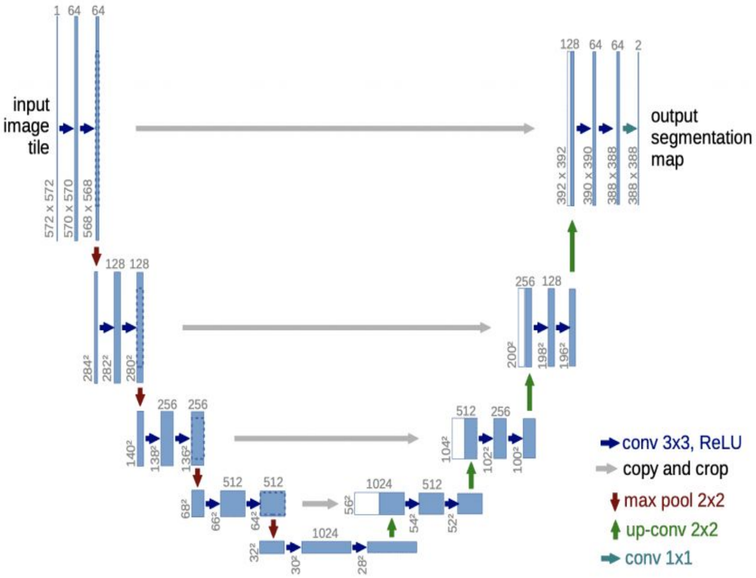
- Our task was to design a CNN's architecture, such as U-Nets, to help improve the accuracy of classifying images from their nutrient deficiencies with the given data set and determine the number of trainable parameters it used.
- We used TensorFlow and Keras to help developed our python code for the architectures.
- The two types of NN's we developed:

  - CNN (Sequential and Functional Models)
  - A more complicated type of CNN called a U-Net

- Then, we train and evaluate each model to determine the accuracy of prediction of the testing data set and the numberable of trainable parameters.

CNN's Models

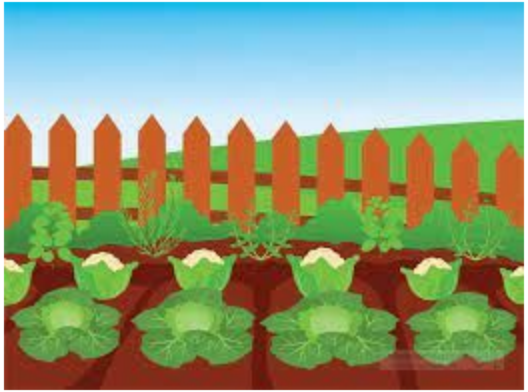




Layer diagrams for our CNN (left) and U-Net (right).

Initial Investment/Cost for traditional

- Equipment Cost $132,925
- Cost of Irrigation Per Acre $1,216.50
- Average cost of an acre of farmland in Louisiana $3,240
- Combined for 5 acres = 5(4456.5) = $22,282.50
- Total Initial Cost $155,207.50



Traditional 5 Acre Farm Yearly Costs

Variable Cost: Roughly $69,793

Fixed Cost: Roughly $11,504

Total Yearly Cost: Roughly $81,297

Freight Farms Initial Investment/Cost

Initial Purchase Cost

- $149,000

Shipping Fee from Boston MA

- $7123.50 ($4.50 per mile on average (1,583 Miles from here to Boston)
- $1,200-$3,000 for Crane to move the shipping container
- Optional Training

Initial investment - Roughly $160,000-$170,000

Yearly Cost For Freight Farm

Supplies: Substrate, Nutrients and solutions: $7,210

Equipment/Maintenance: Cleaning Supplies: $1,500 Maintenance: $2,000-$3,000

CO2 Tank rental and Refill: $2,000

Plastic Clamshell: $40 per 100 and need 1000 every 4 weeks = $5200

Energy usage: Roughly 190 kWh per day at $0.1 per kWh = $6935

Water usage: Minimal

Farm Software: $2,400 a year

One freight farm requires on average 30 hours of labor per week

Yearly costs: $26,245 + cost of 1560 hours of farming labor

Product-Market Fit

- Geographic Constraints
  - Companies, such as Freight Farms, are mainly focused on selling to areas where cooling systems will be most cost effective
  - The extreme heat in places such as Louisiana lower overall demand, in turn forcing much higher prices
- Ideal Consumers
  - These companies have also identified wealthy agricultural companies as their main consumers.
  - Companies, comparable to the Kimbal Musk backed Square Roots, are the only ones who can pay the exuberant prices to buy these shipping container farms.
  - These companies are also in connection with much larger food markets, which allows for a more achievable return on their investment

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