DEEP LEARNING FOR HYDROPONIC SOYBEAN GROWTH

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**Concept of Operations**

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Concept of Operations

for

Deep Learning for Hydroponic Soybean Growth

Team <Sad Aggie Football Fans>

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# Executive Summary

The purpose of this project is to create a deep learning model that will be able to identify growth parameters of soybeans grown with hydroponic techniques. Particularly, the model will use feature extraction to identify the day of growth and nutrient concentration for any given image of a hydroponic soybean. In this project, we will be annotating images collected during the first 29 days of growth of hydroponic soybeans grown in a controlled lab environment. The samples were cultivated in three different concentrations of magnesium, potassium, or nitrogen. Additionally, there were samples in Plasma Activated Water, and the control samples were in distilled water alone. The annotated images of the samples over this period will be used to train the deep learning model. This will be done by inputting each image, its corresponding dataset being labeled in the annotation, so that the model learns the features of the soybeans that coincide with each day of the growth cycle. In addition to the deep learning model, there shall be a user interface produced over the duration of this project. It shall allow a user to input multiple images at a time and shall display the dataset that was output by the model.

# Introduction

The purpose of this document is to present Deep Learning for Hydroponic Soybean Growth, a trained software for identifying stages of growth and nutrient concentrations of soybeans in hydroponics. This project has the potential to help soybean growers worldwide and could even be expanded for further stages of soybean growth, soybeans not grown hydroponically, and even to other plants.

## Background

Agriculture is a primary industry in our world today, and it has been for centuries. As food is necessary for sustaining life, we’ve been reliant on agricultural practices since the beginning of humanity. As population increases, and therefore demand for food increases, the agriculture industry has needed to adapt to be more efficient over time. This has been possible by using new technologies modified for the applications necessary. Not to forget, availability of farmland also continues to shrink for various reasons, furthering the necessity of cutting-edge engineering for the purpose of efficiency and quality in production.

AI, machine learning, and deep learning are employed primarily to process large amounts of data quickly and efficiently. They’re able to process a great deal more than any individual or group of people could, and significantly faster as well. Deep learning is a neural network that attempts to simulate a human brain in how it processes information. The models “learn” by taking in significant amounts of data and examples. Typically, the more examples that are used to train the model, the more precise it will be. Deep learning can process more unstructured data, such as images, automating feature extraction. The trained models can identify different features in an image to categorize what is shown. An example that an IBM article gives is sorting images of pets into “‘cat’, ‘dog’, ‘hamster’, et cetera” [IBM]. The algorithm may identify the ears, the nose, or the tail to determine which category each image belongs to.

Although AI is suitable for use in many fields, we'd say it's essential in those that are necessary for human life. These are the sectors of healthcare, education, and the food industry as a whole. In healthcare, there are intangible amounts of data. Doctors are well-trained, educated beings, but even they make mistakes, or miss something in a patient’s history that could help identify the cause of a current health issue. Many times, there is no room for error. The efficiency and accuracy of deep learning AI models can help with processing patient information to correctly determine the problem, causes, and recommend solutions. Similarly, farmers have a lot of data at their fingertips daily, and deep learning models can aid in processing this data so it can be used to improve different aspects of production.

## Overview

The project will consist of a trained deep learning model and a user interface that will interact with the trained model. The user interface will ideally be a website in which a user can input multiple images at a time for the model to process and output the specified dataset to the user interface. Below is the block diagram for the overall system.

Diagram

Description automatically generated

***Figure 1:*** *Block Diagram of System*

## Referenced Documents and Standards

[1] *Hydroponic Systems*. (2017, January 26). University of Massachusetts Amherst – Center for Agriculture, Food, and the Environment. *Hydroponic Systems.* Retrieved September 9, 2022 from <https://ag.umass.edu/greenhouse-floriculture/fact-sheets/hydroponic-systems>

[2] *Benefits of Hydroponics: The Future of Farming.* (2022, February 11). Green Our Planet. Retrieved September 9, 2022 from <https://greenourplanet.org/hydroponics/benefits-of-hydroponics/>.

[3] IBM Cloud Education. (2020, May 1). IBM. *What Is Deep Learning?* Retrieved September 12, 2022 from <https://www.ibm.com/cloud/learn/deep-learning>.

[4] Liu, Simon Y. “Artificial Intelligence (AI) in Agriculture.” *IT Professional*, vol. 22, no. 3, 2020, pp. 14–15., <https://doi.org/10.1109/mitp.2020.2986121>.

# Operating Concept

## Scope

The Deep learning software for hydroponic soybean growth will be utilized within any situation requiring the user to identify lab-grown soybeans. The model will be trained with image data provided by the agricultural department, and thus will be used in similar situations in which the model identifies the stage of growth and solution in which the soybean is grown. For scale purposes, this will only be used with soybeans grown hydroponically in labs, and not any soybean plant in any condition.

## Operational Description and Constraints

Our project will be used to identify the day of growth and the nutrient concentration of a hydroponic soybean plant. To achieve this, our deep learning model will take an image as input and use its knowledge to identify growth parameters. It will then output the information specified above. Some constraints must be taken into consideration:

* There may be overlap between plants, so the model must be able to handle those situations.
* The model must be able to handle different lighting conditions.
* The model must take into consideration that the soybeans are grown in distilled water alone from days 1-8, and a nutrient solution from days 9-28.

## System Description

Deep Learning for Hydroponic Soybean Growth is separated into three phases: image processing, model training, and user interface development. Both software-based phases are described below.

**Image Processing:** In the image processing phase, first we will take the images collected from the growth process of the plants and annotate them. This is to collect important information about the plants and identify this manually, giving each image a label that is consistent throughout the set of images. Then, these labeled images will be fed into a computer program that will output a dataset corresponding to each given image. These dataset outputs are used as inputs for the model training phase.

**Model Training:** In the model training phase, we will be inputting images and the datasets associated with each image. One of the images that will be used to train our deep learning model is shown in *Figure 1*.

**User Interface Development:** For this subsystem, we will be creating a website through Amazon Web Services, AWS, for the usage of the deep learning model we have trained.

A hand holding a plant

Description automatically generated with low confidence

***Figure 2:*** *Image of Soybean with Magnesium Concentration of 30ppm on Day 15*

## Modes of Operations

The Soybean Hydroponics system will have two primary modes of operation, in which it will be used. As the system is simply software to be used within a larger scoped project, the two main modes of operation are:

**Active**

The active mode of operation refers to when the user inputs an image into the software. The user is given the ability to input an image as the input, and receive the output day of growth, as well as the output hydroponic solution for growth.

**Idle**

Idle refers to the mode of operation in which the user is not inputting an image into the machine learning model, and the system is not being used.

## Users

The proposed system will be utilized as a subsystem for a much larger system design. Potential users include researchers within the agricultural department within and outside of Texas A&M University. As these groups of people both deal with tracking soybean growth within different environments, our software will automate the process, and in turn, reduce the execution time of research tasks. As the software will input an image and output a day of growth and a solution of growth. Some software literacy is required to use the system, so the researchers must have some knowledge of using it.

## Support

After creating this product, we plan on providing an instruction/user manual on how to use the software in the system, as well as documentation behind the code itself, and how the deep learning model works. There will be instructions on how to operate the user interface and guidelines for the type of input the model can accept and process.

# Scenarios

Since our project will not produce an end-user product, but is an intermediate stage of a larger project, there are limited uses for what our team will produce by the end of this course. Eventually, the model we train will be used to create an end-user product that could be sold or otherwise marketed for uses that will not be listed here. At this time, we do not know what the end goal of this overarching project is; therefore, in this section, we can only describe how our model can be used.

## Agricultural Research Use

Researchers in agriculture departments would be able to use our model to expand the depth of their research.

## Engineering Research Use

Research in engineering fields shall be able to use the model as a basis to build more complex models, or to widen the capabilities of this one.

## Use by Farmers and Others in Industry

In farming/growing, it can be useful to offset planting dates for a variety of reasons, and this model could in the process to ensure that all plants are grown to maturity.

## Plant Rehabilitation Efforts

For those who rehab plants, this tool could be useful in identifying the age of the plant, so they can determine the care necessary moving forward with their rehabilitation efforts.

# Analysis

## Summary of Proposed Improvements

* The system will automate the workflow of identifying the type of solution that a soybean plant is grown in.
* The system will automate the workflow of identifying the day of growth of a soybean plant.
* The software utilizes deep learning, and therefore is easily modifiable and trainable.
* This system provides a solution to re-label subjects that have lost any or all methods of identification.

## Disadvantages and Limitations

Because our project is specifically based on hydroponically grown soybeans, the final model will only be trained to this, and therefore is limited by it. The model would not necessarily be able to be employed for soybeans grown conventionally or otherwise and will not support any other plant. Not only this, but as our model will be trained by data specifically with a lab background, even if the plants were grown hydroponically, if the image had a different background, it would be difficult for the model to accurately classify the image. The image quality also determines the accuracy of the classification, as the

## Alternatives

There are a few alternatives to our proposed solution. The first alternative consists of creating a manual workflow to label images based off recognizable plant attributes. There are many issues with this approach. The first is the copious amounts of time that it will take to recognize and label the images. As there can be any amount of or types of data to be processed, this method will result in uncertainty in the recognition of the stage of growth for the dataset, as the individual would need to label each plant individually, in comparison to our solution, which would label all the plants in the image at once.

Another alternative solution to utilizing deep learning for recognizing hydroponically grown soybeans at different stages in time with different solutions would be to hard code parameters in the image recognition process with specific image processing techniques. This alternative is not nearly as effective as utilizing deep learning techniques, specifically image classification, because there are many variables that exist within the dataset, and thus there would have to be a disproportionate number of parameters to satisfy those variables.

## Impact

In terms of the environment, sustainable and ‘green’ solutions are very important these days. Hydroponics itself is a very efficient and eco-friendly way to grow a variety of plants. As opposed to conventional, soil-grown plants, hydroponics allows crops to be grown in places that do not have proper environments or soil suitable for growth. In addition, hydroponics reduces water consumption, and many growth systems recycle water, which is a plus on the sustainable side of things.  Another substantial advantage of hydroponics that is ecologically sound, is the space component. There is limited land on this planet, and the volume of land available for farming is only shrinking over time. Hydroponics offers the capability to expand vertically, almost like the adaptation of New York City and all its skyscrapers: there was no more room to grow outwardly, so they just went upwards instead.