AN INTELLIGENT PLANT DISEASE DETECTION SYSTEM FOR SMART HYDROPONIC USING CONVOLUTIONAL NEURAL NETWORK

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ABSTRACT

- Abstract—Recently, researchers proposed automation of hydroponic systems to improve efficiency and minimize manpower requirements. Thus increasing profit and farm produce. However, a fully automated hydroponic system should be able to identify cases such as plant diseases, lack of nutrients, and inadequate water supply. Failure to detect these issues can lead to damage of crops and loss of capital. This paper presents an Intelligent machine learning system for plant disease detection using Deep Convolutional Neural Network (DCNN). The model was trained on a data set of 54,309 instances containing 38 different classes of plant disease. The images were retrieved from a plant village database. The system achieved an Accuracy of 98.0% and AUC precision score of 88.0%.

Index Terms—hydroponic, Raspberry pi, Internet of Things, convolutional neural network.

INTRODUCTION

- **Hydroponics:** is a soil-less technique of crop cultivation [1], [2]. The concept of hydroponic system has been found in a wall painting from ancient Egypt [3].

There are many benefits to hydroponics [2]:
1) Soil is not needed
2) Crops grow faster in hydroponic systems compared to traditional farming
3) Less space is required
4) Since soil is not needed than the crops can be grown and/or moved to any location,
4) crops are not affected by seasonal changes,
5) little or no pesticides and herbicides are needed.

- Usually Hydroponics system are built in controlled environment such as greenhouse, where the plants are carefully monitored, factors such as temperature, humidity, nutrient are managed to stimulate plant grows and maximize productivity. However, plant disease remains the biggest threat to the farmers, it poses many dangers to the food security and economic security at large.

- To ease the processes and labor intensive work that farmers goes through in finding extension workers that will diagnose their plants when faced with diseases problem, we proposed an intelligent plant disease detection system using Convolutional Neural Network CNN

STATEMENT OF THE PROBLEM

Plant diseases poses a lot of dangers to farmers, as it is difficult to detect the exact type of disease affecting the plant due to inadequate agricultural extension workers, who have the sole responsibility of supervising local farmers in their respective communities and provide them with plant diagnosis, proper solutions and advice. Failure to detect these diseases results in low crop yield, which causes hunger and threat to food security. With the advent of machine learning technology, it is possible to develop a system capable of delivering the task of extension workers efficiently at a low cost.

RELATED WORKS

- Fernandes et al.[15] developed an Arduino and Raspberry Pi-based system for hydroponic monitoring, the system allow external users and programmers to connect to the Pi via the internet. The system was able to control the temperature and humidity of the greenhouse-based hydroponic system.

The system improves the efficiency of the growth of crops. The system was proven to be much faster compared with traditional techniques. It paved the way for smart hydroponic system using internet of things.

- Gartphol et al [16]. developed predictive model for Lettuce quality from the Internet of Things-based hydroponic farms. The authors developed a smart hydroponic to control lettuce farm operation in real-time. Among the items monitored are amount and intensity of light, humidity, temperature, together with weekly measurements of plant growth.

- In [17], a Bayesian Network was proposed for classification of plant disease, it was reported to obtained 84.53% accuracy and 66.67% more yielded crops than the manual system.

- Fuzzy logic has been used to solve a variety of problems in an automated hydroponic system as demonstrate in the work of Musmah et al [18].

IoT-based hydroponics system was already designed before, but automated hydroponic with plant disease detection functions using deep learning was not seen throughout our review of the literature.

AIM AND OBJECTIVES

The main aim of the this research work is to provide an intelligent plant disease detection model that can be deployed on embedded device, to be use in smart hydroponics system for automated disease detection. The system has the following specific objectives:

1- To provide a CNN model capable of detecting plant disease
2- To deploy the model on embedded device and integrate in smart hydroponics system

PROPOSED SYSTEM

1- The propose system setup was shown in Fig 4. (from right)

2- The system make use of Raspberry Pi and Pi camera Module to capture the image of plant leaves for classification

3- The system processed the image and provides an output about the status of the plant on Pi screen.

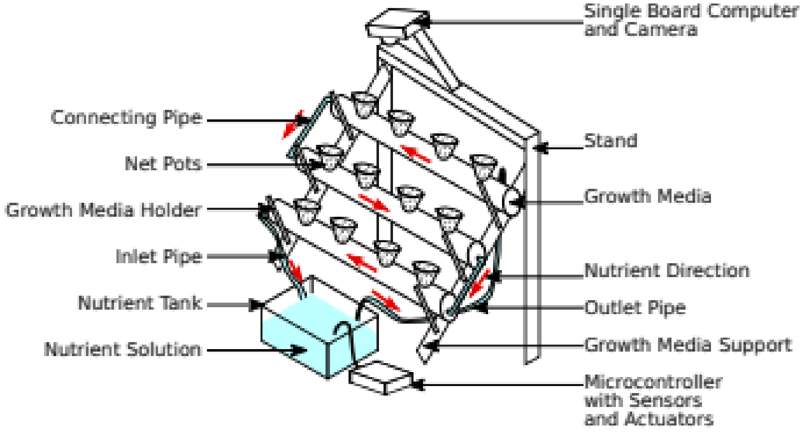


Fig. 4. A proposed system setup.

SYSTEM PHASES

01 GETTING INPUT

Plant leaf serve as input to the proposed system

02 CLASSIFICATION

The image is fed into CNN model which is available on raspberry Pi

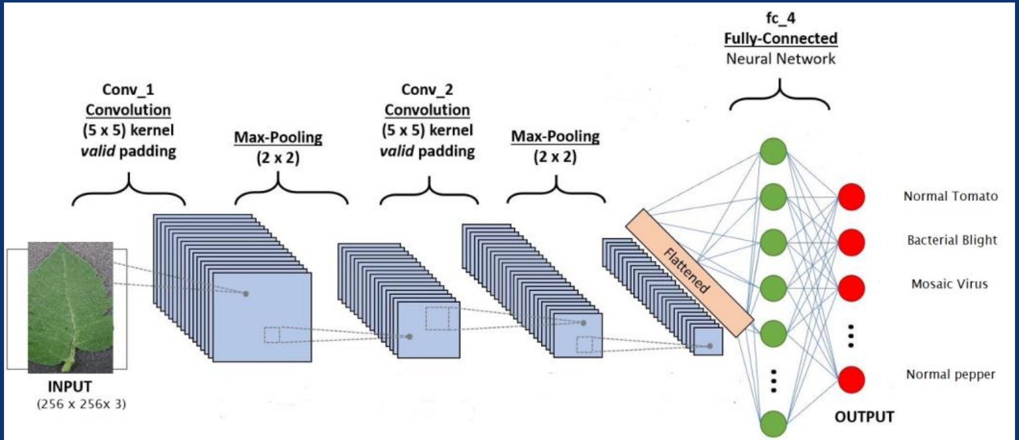
03 OUTPUT

Display the status of the plant under investigation.

CONVOLUTIONAL NEURAL NETWORK (CNN)

- Convolutional Neural Network (CNN) is an ANN that has more than one layer and trains its models by adjusting its weights using optimization methods such as gradient descent algorithms [11].

- The first layer in the CNN is the ”convolution layer” which uses the operation of convolution to search for patterns. Neurons in this network are used to perform the convolution operations, i.e. filtering images to look for patterns.
- The neurons in each given filter share the same weight and bias thus giving them the ability to search for the same pattern in different parts of the image. The second layer is the “rectified linear unit layer” which focuses on building up the patterns discovered by the convolution layer.
- The third layer in the CNN is the ”pooling layer”. This layer reduces the number of patterns allowing the neural network to focus only on important patterns. The final layer is called the fully ”Connected layer” which makes the CNN able to classify data into appropriate labels



Proposed Algorithm for the proposed model:

1. $input\ X$
2. Ꝁ= X : X is transformed into a vector Ꝁ containing features extracted from X
3. $Rz = max(0, z)$: Relu activation function is initiated
4. Model(W) + p(Maxpooling2d): where is P is pooling layer
5. Ậ $= f(p)$: Flattening F is activated to conver 2d array from p to vector Ậ
6. $W = FCL$(Ậ): Ậ is fed into fully connected layer (FCL) for classification
7. $Y = softmax(W)$: Softmax activation function is applied to generate output labels

LEARNING ALGORITHM

- From equation 1: the input vector is multiplied with the weight and bias which are randomly initialized.
- From equation 2: a softmax activation function is applied to Z
- To understand how well the model is doing a cross entropy is used in equation 3 to investigate the error.
- To make the model more optimal a new set of values for weight and bias needs to be obtained that will minimized the errors using back propagation techniques.

$Z = W^T A + b$ -----------------------------------(1)

O= softmax(Z)-----------------------------------(2)

Where:

Softmax function $f(Z) = \frac{e^{zj}}{\sum_k e^{zj}}$)

For j= 1,…,k

$CE = (y' - O)^2$ ---------------------------------(3)

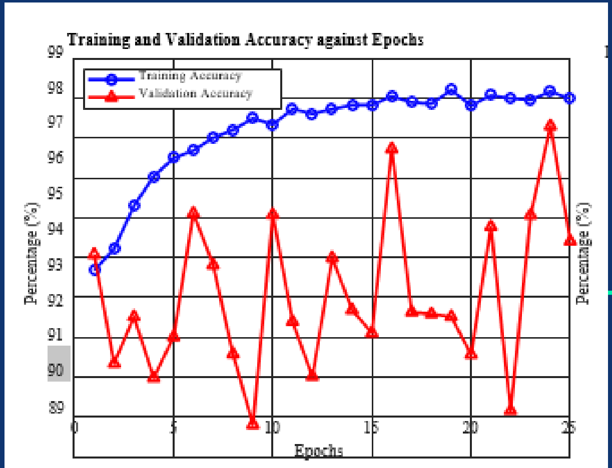
New_param = old_param−(learning_rate∗gradient_of parameter)

Experiment Setup

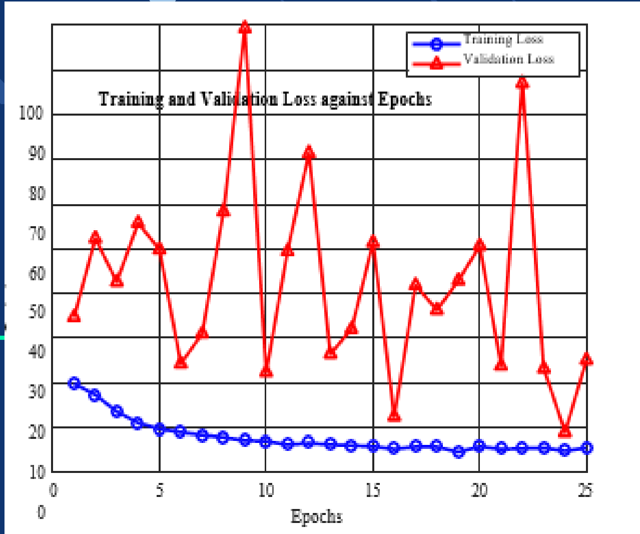
The model was implemented using python programming language, it was train and tested on Plant village dataset which contains 38 different classes of plant disease affecting different plants such as Tomato, Pepper, Potato and the rest. The dataset has 54,309 instances. The model was train on high performance computer with GPU specifically the computer has the following features.

Machine Type Instances	Nvidia Tesla P100
Graphic Processing Unit GPUs	2
High Bandwidth Memory(HBMs)	32GB
Virtual central processing unit(VCPUs)	1-32GB
Storage	1-208

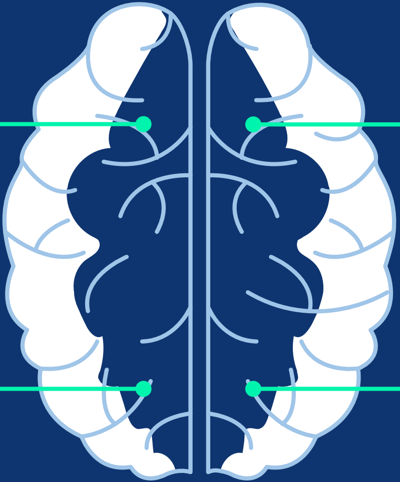
RESULTS

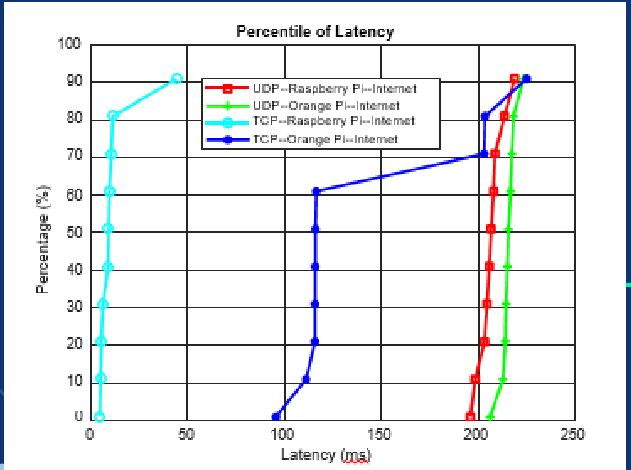


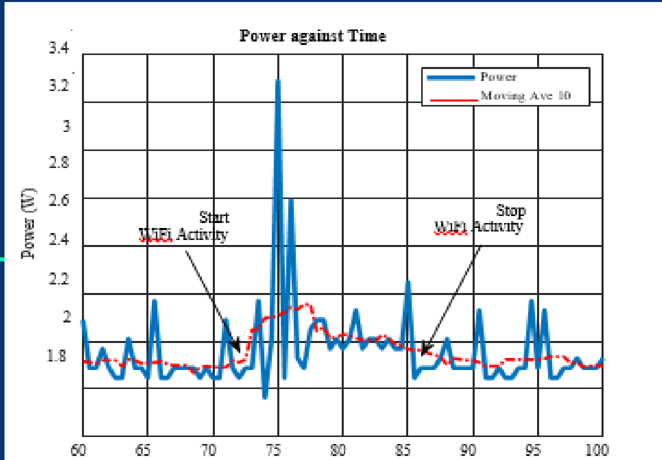
(a) Training and Validation Accuracy of the Model



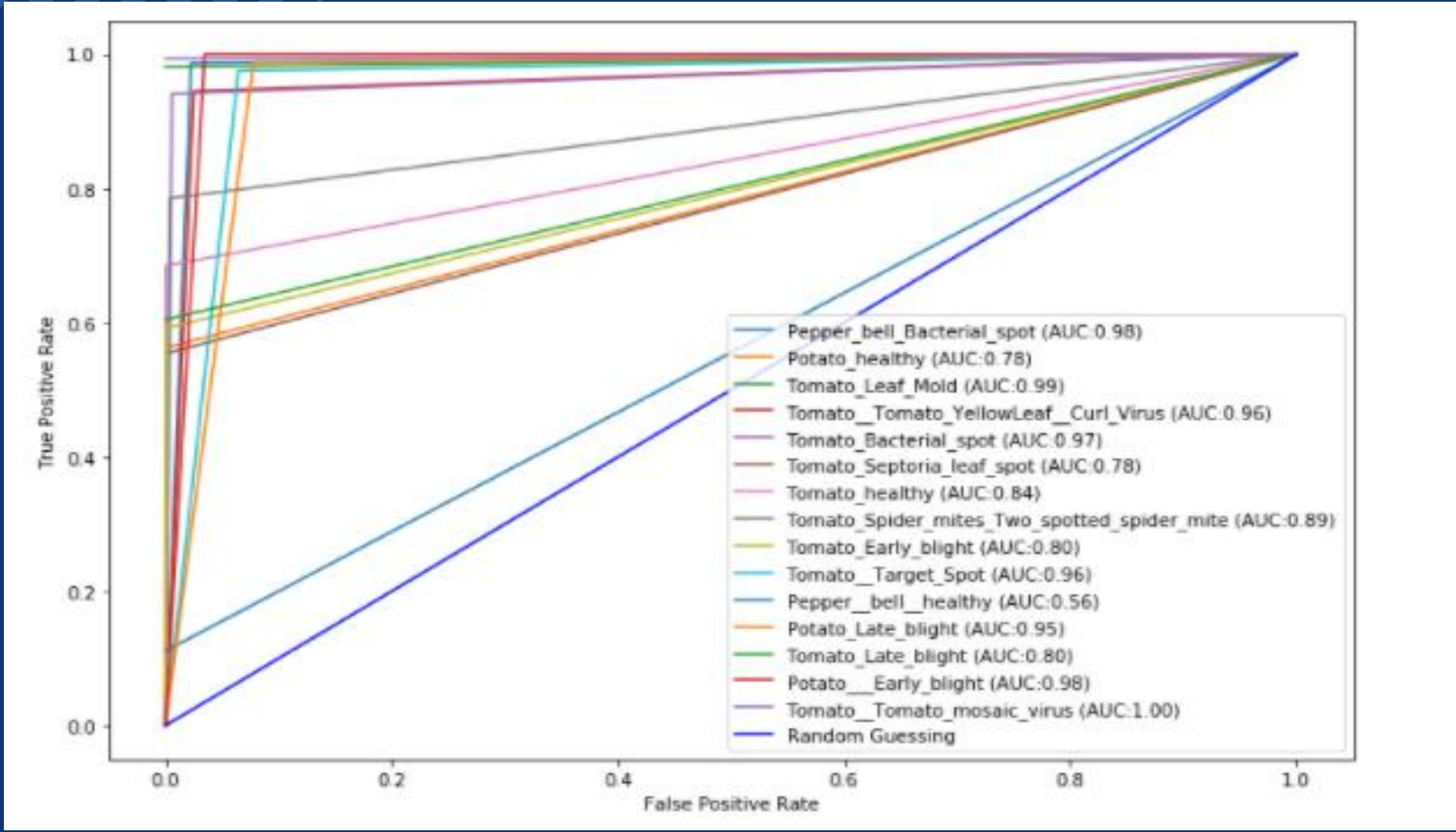
(b) Training and Validation Loss of the Model







ROC CURVE


True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
Pepper_bell_Bacterial_spot (AUC:0.98)
Potato_healthy (AUC:0.78)
Tomato_Leaf_Mold (AUC:0.99)
Tomato__Tomato_YellowLeaf__Curl_Virus (AUC:0.96)
Tomato_Bacterial_spot (AUC:0.97)
Tomato_Septoria_leaf_spot (AUC:0.78)
Tomato_healthy (AUC:0.84)
Tomato_Spider_mites_Two_spotted_spider_mite (AUC:0.89)
Tomato_Early_blight (AUC:0.80)
Tomato__Target_Spot (AUC:0.96)
Pepper__bell__healthy (AUC:0.56)
Potato_Late_blight (AUC:0.95)
Tomato_Late_blight (AUC:0.80)
Potato___Early_blight (AUC:0.98)
Tomato__Tomato_mosaic_virus (AUC:1.00)
Random Guessing

MODEL COMPARISON

Models	AUTHORS	ACCURACY	CHALLENGE
Plant Disease Detection Using Image Processing and Machine Learning	Pranesh, K., et al. 2017.	93%	Consider 5 different plants with 20 classes of disease
Integrating SOMs and a Bayesian Classifier for Segmenting Diseased Plants in Uncontrolled Environments.	Hernández-Rabadán, D. L., Ramos-Quintana, F., and Guerrero Juk, J. 2014.	97%	Focus on diseases that affects tomatoes only
Image based Plant Disease Detection in Pomegranate Plant for Bacterial Blight	Sharath D M, et al 2019.	80%	Consider a single class of disease bacterial blight alone.
Proposed Model	Musa, A., et al 2021	98%	Consider 8 different plants with 38 different classes of diseases.

CONCLUSION

In this paper, we presented a novel approach to plant disease detection in smart hydroponics using deep learning. Plant disease poses a big threat to farmers, using control farming environment like smart hydroponics minimized the risk factors such as drought, high temperature lack of nutrients and so on. Nevertheless, plant diseases contributes immensely to the poor crop yield, causing danger to food security. Therefore this paper presents a deep learning approach for detecting plant disease in smart hydroponics that will aid in diagnosing plant conditions, providing a tool to the farmers capable of doing the task of an agricultural extension worker with ease of access and good accuracy. The proposed model was aimed at improving the efficiency of the manual process and minimizing manpower, saving capital, and improved crop yield. The model was able to achieve a start of the art accuracy of 98% and ROC AUC score of 88%. The model was also tested on Raspberry pi to measure the latency of the system when communicating via Internet and power consumption when deployed, the results show that the latency of the system is less when communicating using TCP protocol

THANK YOU!

Do you have any
questions?

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