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Continuous Monitoring of Lettuce Growth in Hydroponic System

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Abstract
In good old days, traditional farming was in practise where soil was the medium for cultivation. Soil based agriculture uses pesticides to eliminate soil borne pests and disease, as the crops are harmed by insects and few crops are affected by diseases. The crops must be protected against pests and insects to get maximum yield [1]. Use of pesticides can cause soil erosion, air and water pollution. Disease in plant can also cause loss in production and economy hence to overcome this issue plant has to be monitored continuously. If disease is identified earlier, preventive measure can be taken. In this paper, hydroponic system is setup and lettuce are grown in the nutrient rich solution. Essential parameters like pH, EC, temperature of the nutrient solution is also monitored every day. The machine learning algorithm is built using MATLAB. The features are extracted using GLCM of both healthy and unhealthy. Using CNN convolutional neural network algorithm, the leaf is classified either as healthy or unhealthy.
Keywords- hydroponic system, nutrient rich solution, GLCM, CNN

I. INTRODUCTION

Agriculture is the backbone of India. In traditional farming soil erosion, loss of water, plants getting infected by pests, the land under cultivation is decreasing, due to all these reasons the production of crops is decreasing. Hydroponic system of cultivation can overcome all these problems. Hydroponic is a soilless method of cultivating crops where soil is replaced by nutrient solution.

Benefits of hydroponic method of cultivation are: soil is not required, produces higher quality food, requires less space than the plants that are grown in soil, water can be conserved, less labors, produces higher yields, essential nutrients that are supplied in the form of nutrient solution to the root plant are available easily. To ensure optimal nutrient uptake, the pH of the nutrient solution can be monitored and controlled. There are no losses of nutrients (due to leaching) i.e., nutrients do not drain away from the soil.

Identifying plant disease is very difficult as one should have expert knowledge about it. The farmers face a lot of problem in identifying this disease. It is necessary to have experience, knowledge about the plant disease, what are the primitive measures that has to be taken to

control the disease. Earlier detection and monitoring of disease is done manually with the help of experts in this field which is time consuming, requires labor, can be less accurate. Detection of these diseases at the early stage and treating them correctly can increase the production. Hence using machine learning algorithm, the detection of the leaf as healthy or diseased can be predicted.

Lettuce is selected for growing in hydroponic system as it takes 6 to 8 weeks to grow. As lettuce is a leafy vegetable, the leaf of the lettuce can be used to predict the condition of the leaf. The features of the healthy and diseased leaf are extracted using GLCM. Then the network is trained using these datasets to classify/ predict the condition of the test image leaf.

II. RELATED WORK

In [7] using machine learning model it was observed that the plants growth in hydroponic is efficient. Soil was not used throughout the plant growth. The model can learn from data, identify the pattern and make decision based on learning. IoT is used to store data and save it in server (thing speak). Using IoT and machine learning, nature can be predicted, improve farming methods, which crop to produce that saves time and money and also helps farmers from losses that is caused from natural disasters.

In [8] the system can sense, monitor and control automatically the essential parameters like pH, EC, temperature which can affect the plant growth that has a linear relationship with the optimal plant growth. Some algorithms such as fuzzy logic, machine learning, linear regression, image processing can be implemented on the datasets. The correlation between growth rate and input parameters can be understood.

In [9], the faster R-CNN inception V2 and YOLO algorithm were used. Based on training and validation ratio it was categorized into three models. Model A has 78% and 9% training and validation ratio respectively, Model B has training ratio 70% and validation ratio 17% and Model C's training ratio and validation ratio was 61% and 26% respectively. All model's testing ratio was 13% or 53 images. Observations were made and results were obtained,

- F1 score, accuracy and precision were found to be maximum and has a good performance using YOLO algorithm with Model B.
- The performance of the Faster R-CNN inception V2 algorithm with Model C has the lowest of all algorithms and models.
- Model A of Faster R-CNN Inception V2 algorithm has good performance with 70% accuracy, 97% precision 68% recall and 80% F1 score.
- Model C of Faster R-CNN Inception V2 algorithm has lowest performance with 34% accuracy, precision and F1 score.

III. PROPOSED SYSTEM

The proposed system is divided into 2 steps.

Step 1- growing plants in hydroponic system which includes setting up a hydroponic system, germination and growing of lettuce seeds, transplanting into small net plant, preparing nutrient

rich solution, plant growth in nutrient rich solution, parameters to monitor in hydroponic system.

Step 2- developing machine learning algorithm which includes feature extraction using GLCM and machine learning algorithm to predict the condition of the leaf either as healthy or unhealthy.

The plant selected to grow in this hydroponic system is "LETTUCE". The reason for selecting lettuce is because it is extremely fast-growing crop. The leaf of lettuce is ready to consume in 6 to 8 weeks in hydroponics. Lettuce is a leafy vegetable which is scientifically named as "Lactuca sativa".

Step 1 Growing plants in hydroponic system

i. For vertical hydroponic farming a stand is setup as shown in the below figure [1]. PVC pipes of length = 6feet of 4inch pipe. Small holes of 1 inch are drilled in the PVC pipe to place the net pot inside the hole such that only the roots of the plant drown in the nutrient solution. Six similar holes are drilled in each PVC pipe with a distance of 8cm between the holes.

Figure 1 Hydroponic setup stand

ii. The seeds of the lettuce plant are soaked in water overnight for germination. Next day the seeds are sowed in soil. The plants are watered every day. 25 days of plants growth is captured. Alternative days of plant growth images are shown below figure [2].

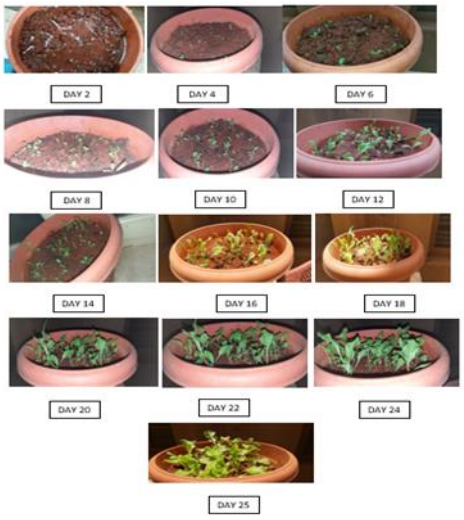

Figure 2 Germination and growing of Lettuce

iii. After certain growth of plant i.e,25 days of growing plant in soil, the plants are separated from the soil carefully and is put up in small net pot as shown in the below figure [3] and placing them inside the PVC pipe hole such that only the roots of the plant is immersed in the nutrient rich solution as shown in figure [4].

Figure 3 Transplanting into small net pot

iv. NPK i.e., nitrogen, phosphorous and potassium are the main nutrients for plant growth. The micro nutrients and macro nutrients are boric acid, manganese sulphate, Magnesium nitrate, ammonium phosphate, sodium nitrate, copper nitrate, zinc nitrate, potassium sulphate. All these nutrients are mixed in water to form nutrient rich solution and continuously check and maintain the pH and EC.

Figure 4 Preparation of nutrient solution and checking the pH, EC, temperature

v. The plant after separating from the soil is put in a net pot and is immersed in the nutrient rich solution where only the plant root is dipped in solution. This technique of growing hydroponic plant is known as nutrient film technique i.e., NFT. Below are the images of the plant growth in the nutrient solution. Every alternative day the images of plant leaf is captured as shown in the below figure [5].

Figure 5 Placing net pot inside the PVC pipe

vi. Plant growth in nutrient rich solution is monitored every day by checking its pH, EC and temperature. If any changes were found in these parameters, changes were made according to the required threshold.

vii. The images of the plant growth is captured on alternative day as shown in the given figure [6].

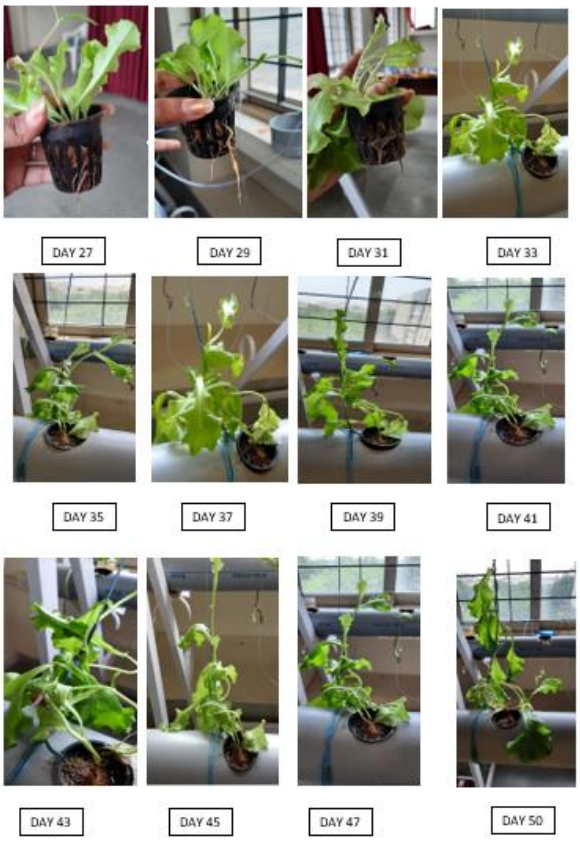

Figure 6 Plant growth in nutrient rich solution

Step 2 -Developing machine learning algorithm

i. Feature extraction using GLCM-

The process of converting image data into numerical features by keeping the information in the original data set is referred as feature extraction. GLCM is used in Image classification problem. The Gray Level Co-occurrence Matrix (GLCM) method is a way of extracting second order statistical texture features. Image is composed of pixel where each pixel has a specific intensity i.e., gray level. The GLCM is a matrix which tells how many times different levels of gray levels co-occur in an image. In this project, energy, contrast, correlation, mean, homogeneity, standard-deviation, entropy are the few features that are extracted using formula.

i. Contrast:

$$\sum_{i,j=0}^{N-1} P_{i,j}\,(i-j)^2$$

ii. Correlation:

$$\sum_{i,j=0}^{N-1} P_{i,j}\left[\frac{(i-\mu_i)(j-\mu_j)}{\sqrt{(\sigma_i^2)(\sigma_j^2)}}\right]$$

iii. Energy

$$\sum_{i,j=0}^{N-1} P_{i,j}^2$$

iv. Homogeneity:

$$\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$$

v. Entropy:

$$\sum_{i,j=0}^{N-1} P_{i,j}\left(-\ln P_{i,j}\right)$$

vi. Mean:

$$\mu_i = \sum_{i,j=0}^{N-1} i\left(P_{i,j}\right) \quad , \quad \mu_j = \sum_{i,j=0}^{N-1} j\left(P_{i,j}\right)$$

vii. Standard deviation:

$$\sigma_i = \sqrt{\sigma_i^2} \quad , \quad \sigma_j = \sqrt{\sigma_j^2}$$

ii. After extracting features of both healthy and unhealthy leaf, it is saved in excel sheet. Around 230 images are taken as the dataset. Now the dataset is split into training, validation and testing.

iii. Contrast, correlation, homogeneity, Energy, standard deviation, mean, entropy are the features that are extracted in this paper. Using machine learning algorithm such as CNN, KNN, Naïve bayes, random forest the condition of the leaf is predicted and accuracy of each algorithm is compared.

IV. RESULTS:

The results obtained from the GLCM code and many machine learning algorithm are discussed here. GLCM is used to extract the features of the leaf images. Machine learning code is used to classify the condition of the image as either healthy or unhealthy.

0.7014	0.8785	0.0629	0.7631	117.6550	73.8571	7.9142	unhealthy
0.5756	0.8955	0.0731	0.7970	104.5517	60.7883	7.7922	healthy

Figure 7 feature extraction

In the above figure [7] the 1st column is contrast, 2nd column is correlation, 3rd is energy, 4th is homogeneity, 5th is mean, 6th is standard deviation, 6th is entropy, 7th column is condition of the leaf.

Training dataset:

3 models are considered based on splitting % of training data, validation data i.e., Model A, Model B, Model C. The splitting % of Model A is 60% as training dataset, 30% as validation dataset. Out of 226 datasets, 135 is training dataset 67 is validation dataset and 24 is testing dataset. The splitting % of Model B is 70% as training dataset, 20% as validation dataset. Out of 226 datasets, 158 is training dataset 45 is validation dataset and 24 is testing dataset. The splitting % of Model C is 80% as training dataset, 10% as validation dataset. Out of 226 datasets, 180 is training dataset 22 is validation dataset and 24 is testing dataset. For all three models testing data is 10% i.e., 24 datasets.

Comparing the accuracy of CNN, random forest, KNN, Naïve Bayes, SVM with different models.

	CNN (%)	**RANDOM_FOREST (%)**	**KNN (%)**	**NAÏVE_BAYES (%)**	**SVM (%)**
MODEL A	**95.8**	**100**	**87.5**	**100**	**95.8**
MODEL B	**100**	**100**	**95.6**	**100**	**100**
MODEL C	**100**	**100**	**95.8**	**100**	**100**

Table 1: Accuracy of CNN, random forest, KNN, Naïve Bayes, SVM with different models.

From the above table (1) it can be observed that Model C has maximum accuracy than the others. This can be concluded as, the more the dataset is given for training the more accurate the network can predict the testing dataset.

Based on the machine learning algorithm the accuracy of KNN was found to be less than other networks.

Accuracy of Random Forest, Naïve bayes for all 3 models was found to be 100%

Accuracy of CNN, SVM was more in Model B and Model C.

i. CONCLUSION AND FUTURE SCOPE:

Hydroponics cultivation was found to be the most effective way of growing plants which proved for better yield, soilless cultivation, reuse of water, requires less space. By using nutrient rich solution, it was found that the plants were healthy than in conventional way of growing plants as the nutrient rich solution is prepared based on the nutrients required by the plants in proper quantity. We also found that the water is not wasted as the nutrient solution can be reused by the plants. It was found that the plant growth was faster and production of the leaf was more. It was proved that the soil has no important role in plants growth. The environment condition that is required by the plant growth is set-up.

The nutrient rich solution is prepared by maintaining the pH, EC and temperature. As pH is the measure of acidity and alkalinity. If pH scale is =7 then it is neutral. If the pH is below 7 then it is acid. If it is above 7 then it is basic. pH affects the availability of nutrients to the plants hence pH has to be maintained to 6 - 6.2. EC measures the potential for an electrical current to be transferred in water. The EC is a measure of the total salts dissolved in the hydroponic nutrient solution. Hence EC has to be monitored periodically to make sure the plants intake nutrients properly. By using GLCM the features of the image are extracted in the form of numerical data. The extracted features are contrast, correlation, energy, entropy, homogeneity, mean and standard deviation. This numerical dataset is fed into CNN network to train, validate and test the network in MATLAB. Accuracy was found to be 95.56%

This can be implemented using XG Booster and can be automated by placing camera to capture images of the leaf on every day bases and IoT based system to sense and monitor pH, EC and dosing essential nutrients to the system automatically with no human intervention.

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