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PLANT GROWTH PREDICTION AND ANALYSIS USING CONVOLUTIONAL NEURAL NETWORKS WITH SUITABLE ACTIVATION FUNCTION

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Abstract

The economic growth of farmers depends on the quality of the products that they produce. Quality relies on the plant's growth and its yield. Based on the study, about 30k hectares of agricultural land is decreasing per year. So to feed the increasing population of India we need more yield on the agricultural land which is under cultivation. Predicting plant growth will help the farmers to take appropriate measures. Prediction also helps the agriculture associated industries for planning their production business. This paper proposes a cost-effective method of predicting the growth of the plant. The embedded system consisting of a camera and raspberry pi developed to capture an image remotely and fed to Convolutional Neural Network (CNN) for accurate prediction. CNN algorithm is used to classify the stages of the plant. The proposed system used to find the area of the leaves which helps in estimating the days remaining for harvesting the plant.

Index Terms—Raspberry Pi, CNN algorithm, prediction, plant growth.

I. INTRODUCTION

In India, agriculture is one of the major industrial sectors where the country's economy depends on it. Due to major factors like climatic changes, excessive use of pesticides, falling groundwater levels and unexpected rainfall are responsible for the reduction in the agriculture output. Based on the study conducted by the Centre for Study of Developing Societies (CSDS) 76 percent of farmers like to give up farming because of the losses they face in agriculture. Most of them like to do small jobs in cities rather than facing losses in agriculture. In India about 30k hectares of agricultural land is decreasing every year. But to feed the increasing population of India we need to increase the crop yield. The production of food grains from the year 2011 to 2018 is shown in the figure1. We can see there is a drastic decline from the year 2013 to 2014 and a slight decrease from 2017 to 2018 [1]. To maintain better improvement in the graph, plant growth prediction will be more useful. The proposed system is the embedded system consisting of a camera module and Raspberry Pi is developed to capture an image remotely and sent to the cloud. These plant images are collected and taken as a dataset for training Convolutional Neural Network for accurate prediction. CNN is a deep learning algorithm which is mostly used to analyze visual images. CNN involves convolution operation and has many hidden layers. This convolution operation extracts features from input images which are fed into the convolution layer with the help of filters. After prediction is done, the matching probabilities of the test image will be predicted. The detailed study can be found in the sections below.

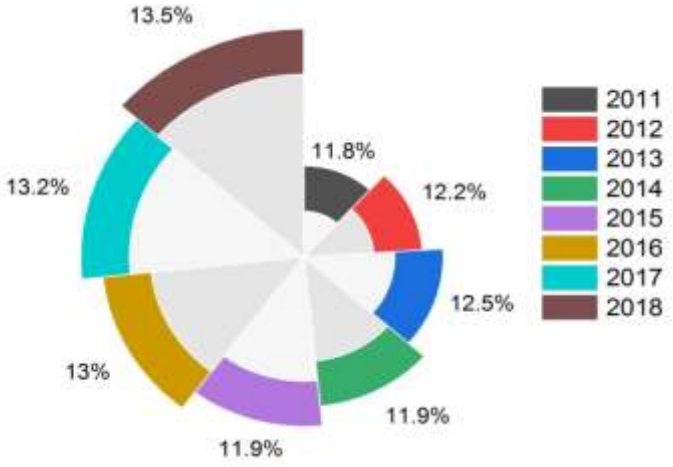

Fig. 1. Grain productions for the years 2011 to 2018 in India.

II. EXISTING SYSTEMS

Dr. Sujata terdal and Renuka proposed a system that uses supervised learning to estimate the cost of crop yield and its quantity. The stages included in this system are as follows. In the dataset collection step, data is collected from different sources, and using these data sets are prepared. Later this data is used for descriptive analysis. The preprocessing step is the second step of the system and it is one of the important steps in machine learning. It is used to insert missing values, data range, and extracting functionality. They have used this null method for checking null values and label encoder for converting the data into numerical data. In the Feature Selection step, it simplifies the amount of data involved to represent a large data set. The soil and crop characteristics taken from the preprocessing step is the final set of training. Random forest classifier method is used for feature selection. Based on the entropy value the features of the attributes are selected. The next step involves separating input data into training and testing sets. The data collected is divided into training data and test data with a division ratio of 70 percent or 30 percent. We get the required data after the preprocessing step and it is processed by a machine learning module. Finally three different machine learning algorithms are applied to data to get the maximum accuracy [2]. Dr. Bharat Mishra and S. Veenadhari conducted a study which mainly focuses on finding out the effect of climatic parameters on crop yield. The area for collecting the data is selected where the particular crop is grown in large quantities. They have collected the data regarding yield and climatic parameters for the corresponding 10 years. H Shriya sahu and Meena Chawla presented a study on a random forest approach for crop yield prediction. In this, they have collected the data in two ways. One is getting existing data through online sources and the other is collecting data as per requirement in there c4.5 based decision tree and Mo2.0 and VC++6.0 are spatial data mining techniques used in this study. In this method the values above the threshold were considered as one set and other as another set. Decision tree is built using the above techniques by which attributes are found with information gain. By using this gain we can find useful attributes. Thus we have obtained the ranking of each attribute. Using this ranking we can select- the attributes to be used in concept description [3].ir programming work by sensor and store it in the cloud. A random forest algorithm is used to classify the given data. Random forest is a decision tree, built by the training sets. This entire decision tree is used to predict each sample of the testing dataset. The data set is processed by the Hadoop framework and the Map Reduce programming model. The programming model of Map Reduce merges the key-value pair to reduce the duplicate entries to get the smallest set of values. Finally, the system Prediction gives the most suitable crop based on the dataset parameters [4][5]. Baisong Chen and Yuchun Pan reported the measurement of the area of a leaf using a digital image. They have taken a digital image of a leaf on the center of white paper with prescribed endpoints with the respective size of the digital camera image. While taking the digital image, the optical axis of the lens should be perpendicular to the white background of the leaf and must focus on the center of the leaf. Using image processing, the background is removed when the RGB value exceeds the recommended value of green pixels. Finally, the number of leaf pixels is calculated and the area of the leaf measured using the equation on scanning pixels and leaf pixels [6]. Shogo Nagano developed leaf movement based on the growth of plants. This work helps to improve productivity in agriculture. Indoor cultivation will have great advantages with this system as it spends a lot of money for the maintenance of environmental conditions. Every plant in the cultivating area may not have proper growth and quality. Such plants must be identified at early stages and extracted from cultivating areas or taken appropriate measures for those plants to grow. The plant growth stages are greening, nursery and cultivating stages. So, visual information of plants is necessary to identify low quality plants. Optical flow analysis and machine learning techniques are used to develop this system. To obtain the plant growth accurately, the angle at which the plant is monitoring is also important and can be achieved by normal vector analysis. Optical flow is nothing but motion estimation between consecutive frames of a plant. Hence, growth is determined by observing the leaf extension of plants [7].

III. HARDWARE IMPLIMENTATION

A. Embedded System Development

The proposed embedded system is shown in the figure 2(a). The embedded system uses raspberry pi as processing unit and camera interfaced to collect the images of plant. The operating system of Raspberry Pi is Raspbian. Raspbian OS is installed in an SD card which is a minimum of 8GB. Once the porting of OS into the SD card is done, insert the SD card into Raspberry Pi and then, it is connected to power.

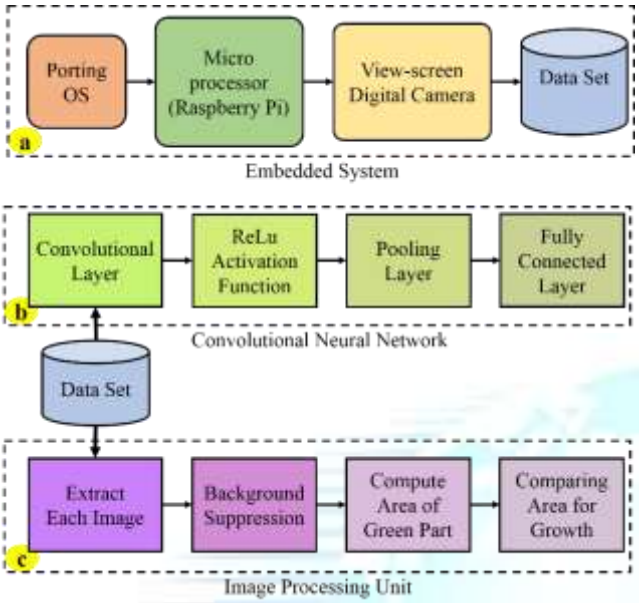

Fig. 2. Overall block diagram. (a). Proposed embedded system (b). Proposed CNN model (c). Proposed image processing unit.

B. Raspberry Pi Camera Module

The Raspberry Pi camera module is equipped for capturing photos and it can be controlled programmatically.

- Sensor type: OmniVision OV5647
- Pixel Count: 2592 1944
- Lens: f=3.6 mm, f/2.9
- Angle of View: 54 41 degrees

C. Dataset Collection

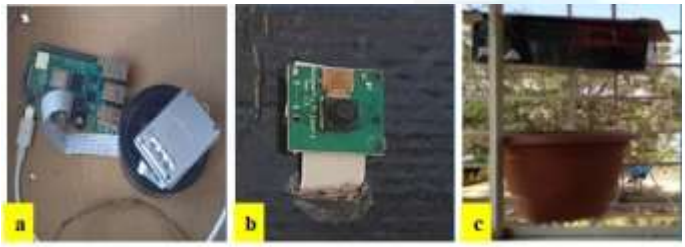

Fig. 3. Onsite model of the system (a). Raspberry Pi (b). Pi camera (c). Image collection of plant.

We need to use the green part of the leaf to predict the growth. To collect the dataset, we take pictures of the plant for about a month or more. This can be easily done by using a raspberry pi and a camera module. The camera is mounted at the top of the plant such that it will cover the entire plant. Raspberry pi is programmed using python language such that it will take a snap at an interval of 20 minutes and we have printed the date and time on the captured image. These images are saved with date and time as a filename. All these images are stored in a folder in which they are divided into 3 separate folders based on their stages. Later, these are used for prediction. The prototype is shown in figure 3(a). The setup uses raspberry pi and camera is shown in figure 3 (b) and 3(c).

IV. METHODOLOGY

A. CNN

The Convolutional Neural Network (CNN) that was first presented by LeCun et al. In 1998 it was described by its parameter-sharing architecture and the idea of an open field [8]. Convolutional Neural Network is a deep learning algorithm which is normally used for identifying images. This algorithm has cluster images by similarity and performs object identification within the scenes. CNN uses unique features of images to spot objects that are placed on the image. This process is too similar to our brain to spot objects. Layers of Convolution Neural Networks.

- Convolution Layer
- ReLu Activation Layer
- Pooling Layer
- Fully Connected Layer
- Softmax Function

B. Convolutional Layer

M.M. Islam et al., proposed a model to identify different types of plants using Convolutional Neural Networks [9].This is the first layer in the Convolutional Neural Network where every image in the dataset is convoluted with the filter matrix. This is done to extract the features of an image by using different filters. When the image is converted to a grayscale, it has a matrix of pixel values.

The convolution operation is performed by sliding this filter over the input data. After this step, matrix size is reduced which makes the further computations easy as shown in figure 4.

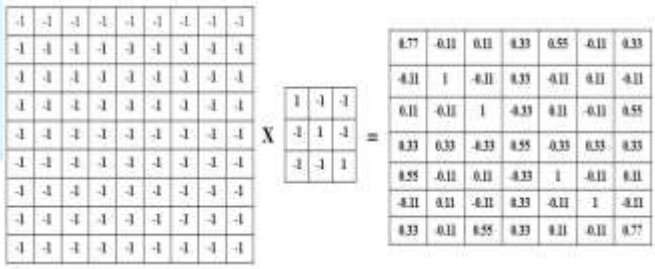

Fig. 4. Convolution operation of Input image and Kernel filter.

C. ReLu Activation Layer

Most of the Neural Networks use ReLu activation functions because it is easy to train and gives better output. The ReLu is a rectified linear activation function that eliminates all the negative values from a given input matrix and replaces them by zero as shown in figure 5. The output of the convolution layer is given as input to the ReLu Layer as shown in figure 6.

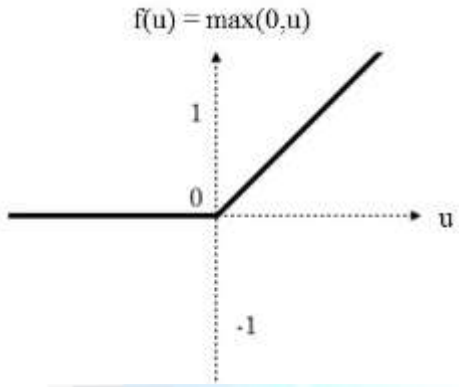

Fig. 5. ReLU activation function.

0.77	-0.11	0.11	0.33	0.55	-0.11	0.33
-0.11	1	-0.11	0.33	-0.11	0.11	-0.11
0.11	-0.11	1	-0.33	0.11	-0.11	0.55
0.33	0.33	-0.33	0.55	-0.33	0.33	0.33
0.55	-0.11	0.11	-0.33	1	-0.11	0.11
-0.11	0.11	-0.11	0.33	-0.11	1	-0.11
0.33	-0.11	0.55	0.33	0.11	-0.11	0.77

→

0.77	0	0.11	0.33	0.55	0	0.33
0	1	0	0.33	0	0.11	0
0.11	0	1	0	0.11	0	0.55
0.33	0.33	0	0.55	0	0.33	0.33
0.55	0	0.11	0	1	0	0.11
0	0.11	0	0.33	0	1	0
0.33	0	0.55	0.33	0.11	0	0.77

Fig. 6. Product of convolved image matrix with ReLu function.

D. Pooling Layer

0.77	-0.11	0.11	0.33	0.55	-0.11	0.33
-0.11	1	-0.11	0.33	-0.11	0.11	-0.11
0.11	-0.11	1	-0.33	0.11	-0.11	0.55
0.33	0.33	-0.33	0.55	-0.33	0.33	0.33
0.55	-0.11	0.11	-0.33	1	-0.11	0.11
-0.11	0.11	-0.11	0.33	-0.11	1	-0.11
0.33	-0.11	0.55	0.33	0.11	-0.11	0.77

→

1.00	0.33	0.55	0.33
0.33	1.00	0.33	0.55
0.55	0.33	1.00	0.11
0.33	0.55	0.11	0.77

Fig. 7. Shrinking 7x7 matrix into 4x4 matrix.

Pooling Layer is used to shrink the matrix size. Three pooling methods are average pooling, max pooling and min pooling. In this layer max pooling is done which is used to select the largest value from a matrix. The output of the ReLu Layer is given as the input to the pooling layer. A window size of two or three is selected and it is moved over the filtered image as shown in figure 7.

E. Fully Connected Layer

The target of a fully connected layer is to take the outputs of the convolution/pooling layers and use them to classify the image into a label. The backpropagation process happens on its own in a fully connected layer of the CNN network to find the most accurate weights. Each neuron gets weights that organize the most suitable label. The actual classification is done in this layer. The above three layers are repeated two or three times, so that the matrix will shrink. The output of the convolution layer/pooling layer is flattened into a single list, each value representing a probability that a certain feature belongs to a label as shown in figure 8.

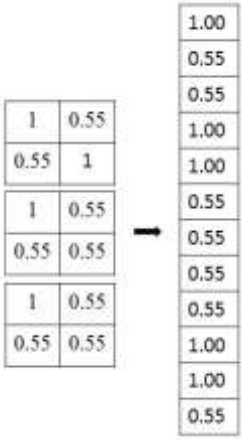

Fig. 8. Shrinking 7x7 matrix into 4x4 matrix.

F. Softmax Funtion

Softmax function is the last layer of CNN. This allows the output to be converted directly as a probability. The output of this layer is in the range of 0 to 1 as shown in figure 9.

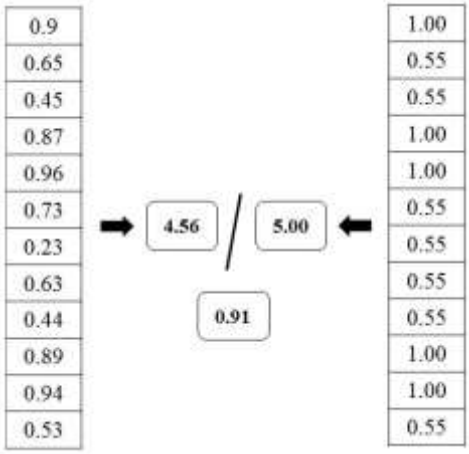

Fig. 9. Probability conversion.

G. Area Calculation

Pandey et, al proposed a non-destructive way of calculating area of leaf using millimeter graph paper method [10].The dataset consists of colored images of palak plants. The images are read as an array of pixel values in RGB format. Every image has three channels that are red, green and blue with each channel having its pixel values. So, to find only green pixels in an image, we need to separate all other colors from the image by a method called Background Suppression. Background suppression is nothing but removing all the colors except green by making the background color as black. For this, we use the Python OpenCV library which has many inbuilt methods for converting images into the required form. This process involves the following steps.

H. Converting Color Space

The RGB image is converted into an HSV image by using the cv2.cvtcolor method. HSV stands for hue, saturation and value for an image. The hue range is from 0 to 179 and both saturation and value range are from 0 to 255.

I. Extraction of Green Color in Image

There are some thresholding methods in the Open-Cv library to detect any color specified in a range. The method used for the extraction is cv2.inRange method and syntax is cv2.inRangesource, lower boundary and upper boundary. This method returns an image with that threshold color. The RGB range of green color used in this is from (36, 25, 25) to (86, 255, 255).

J. Zero Like Array Creation

The zero like array creates an array with the same size and filled with zeros. Numpy .zeroslike function is used for the creation of a zero array. Each image is composed of pixels and when these values are taken out using python, four values are acquired for each pixel (R, G, B, A). This is known as the RGBA color space which contains Red, Green, Blue colors and Alpha value respectively. Each pixel value can be extracted and stored in a list. A getdata() function of the Image module is used to extract the pixel values. The image is scanned horizontally from left to right starting at the top-left corner. The values received from each pixel are then appended to a list. Finally, we receive a list with each pixel value as a set of 3 values(R, G, B). Now, only green pixels can be extracted from the list so that only the plant part is obtained. These green pixels can be treated as areas of the plant. By comparing areas in a month, the plant growth is determined.

V. MATHEMATICAL MODEL OF CNN

In Convolution layer, Let 'f' be the input image and 'G' be the output then

$$G\,[M, N] = (f * h)\,[M, N] = h\,[j, k]\;\; f\,[m - j, n - k]$$

Where h = Kernal

[m, n] are matrix sizes j, k are input images

In Relu fucntion

$$G_1 = 0 \qquad \text{if } x_i < 0$$

$$G_1 = 1 \qquad \text{if } x_i > 0$$

Where h = Kernal [m,n] are matrix sizes,

j, k are input images

In pooling layer

$$G_2\,[j, k] = Max\,(G_1\,[m, n])$$

Where m, n and j, k are matrix dimensions.

In fully connected layer

$$Z = f\sum_{i=1}^{n}(x_i * w_i + b)$$

$Where\ z$ is the resultant output,

x_i is the image from the pooling layer,

w_i is the colomn matrix,

b is the random bias.

S.V.V.V et al proposed a plant growth model by collect plant images using drones and satellites and applying a complex network approach for prediction [11].

VI. RESULTS AND DISCUSSION

Plant images are collected every day using the proposed system. The images are labeled with data and time as shown in the figure 10. A test image is given as input to predict the stage of the plant. The RGB image as shown in figure 11(a) is converted in to HSV (Hue, Saturation, Value). HSV is nonlinear transformation of RGB image. HSV image of plant is shown in figure 11(b).Threshold image can be seen in the figure 11(b). Background of the plant is eliminated to calculate area of plant using green color of the plant as shown in figure 11(c). Using area of the leaf plant growth can be estimated. Input image as plant is given to CNN. After training is done, the output will be in terms of probabilities for every stage. These probabilities for every stage are calculated based on input image matching probability with the trained dataset. The stage with higher probability is the stage of the given input image. Figure12 shows the output of probabilities which predicts that img1.jpg (test image) belongs to stage 1. The dataset of the plant is fed as input to find the area of the leaf. The areas of the dataset are compared and the growth of the plant along with the number of days it took to grow is determined.

Fig. 10. Different stages of spinach plant growth.

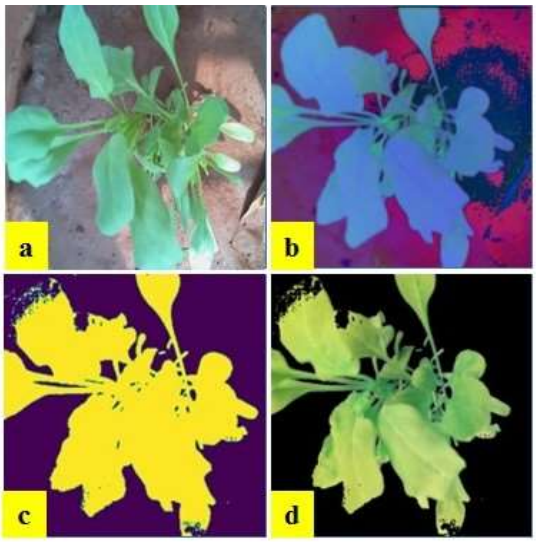

Fig. 11. (a). Spinash plant (b). HSV image of the plant (c). Threshold image of the plant (d). Background separated image of the plant.

```
The dates on which images are captured:
['20-02-20', '20-02-20', '20-02-20', '20-02-21',
The length of images1 list ( number of images):
46
Areas in terms of pixels of each image:
[64213, 129022, 129473, 241986, 294381, 430406,
Maximum area in pixels :  7129398
Minimum area in pixels :  64213
Maximum area index 38 Minimum area index 0
Maximum area image date 20-03-11
Minimum area image date 20-02-20
The growth is 7065185 in 20 days.
```

Fig. 12. Output showing probabilities of stages of given input image.

VII. CONCLUSION

System is developed using neural network model for plant growth prediction and achieving good prediction accuracy in classifying stages of plant growth. This is also useful for farmers for predicting plant growth and based on that they can think which plant should be harvested to get maximum yield. This can be helpful to predict the yield of various plants. This model can also be used to predicted different crops. Existing model can be trained with different crop images and can be used to predict the growth of plant.

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