Survey on Identifying Nutrition Deficiency in Plants/Crops using Computer Vision

Nikitha S,Prabhanjan S, Prajwal A R, Shishira Nataraj, Shravan N
Department of computer science and engineering
Jyothy Institute of Technology, Bangalore

Abstract

Computer vision is concerned with the theory and technology for building artificial systems that obtain information from images. Computer vision is widely used in the medical field for diagnosis of a patient, industry for supporting manufacturing process, military for detection of enemy soldiers or vehicles and missile guidance, designing autonomous vehicles and in agriculture for field robots, phenotyping, grading and sorting, livestock identification and identification of diseases and nutrition deficiency in plants/crops. Applying computer vision with connected algorithms to any data set can yield exciting results that surpass existing methods in both features and accuracy. Extensive research is being done on using computer vision in agriculture. Identifying nutrition deficiency in plants/crops using visual symptoms is still in an early stage. Timely identification of nutrient deficiency in the plants can help farmers in the management of chemical fertilizer application. The overuse of fertilizers has become a common phenomenon in field management, which has led to the serious adverse effect on plant growth, soil, air and water. This paper reviews various techniques adopted in last 10 years to identify nutrition deficiency in plants using computer vision.

Introduction

Eyes are major sensory inputs with which humans see. The brain processes the visual input to sense the world around them. Computer vision is a field of artificial intelligence and computer science that aims to give a similar, if not better, the capability to a machine or computer. The processes involved in computer vision typically is to extract the features automatically, analyze it and make sense of the features from a single or a sequence of images. The process of automatic visual understanding involves crafting theoretical and algorithmic bases. The goal of computer vision is to develop algorithms that allow a computer to “see”.

Computer vision is widely used in the medical field for diagnosis of a patient, industry for supporting manufacturing process, military for detection of enemy soldiers or vehicles and missile guidance, designing autonomous vehicles and in agriculture for field robots, phenotyping, grading and sorting, livestock identification and identification of diseases and nutrition deficiency in plants/crops. Each of the application areas uses a range of computer vision tasks; namely recognition, identification, detection, content-based image retrieval, optical character recognition, motion, scene reconstruction, image restoration and etc.

Applying computer vision with connected algorithms to any data set can yield exciting results that surpass existing methods in both features and accuracy. Extensive research is being done on using computer vision in agriculture. Identifying nutrition deficiency in plants/crops using visual symptoms is still in an early stage. Timely identification of nutrient deficiency in the plants can help farmers in the management of chemical fertilizer application. Chemical fertilizers are rich in nutrient content. Chemical fertilizers help the farmers in increasing crop production. The overuse of fertilizers has become a common phenomenon in field management, which has led to the serious adverse effect on plant growth, soil, air and water. Over application of chemical fertilizer to plant leads to leaf scorch. Excess nitrogen used in crop fertilizers leads to release of greenhouse gases into the atmosphere. The overuse of chemical fertilizers can lead to soil acidification and depletes the soil essential nutrients. Excess nutrients in water reduce the amount of oxygen. Therefore, timely detection of nutritional deficiencies in plants is necessary for precision management of fertilization and agricultural sustainability.

The plant leaf tissue analysis has revealed the presence of about 60 elements in the leaf. Extensive research carried out on the aspects of plant nutrition has established the essentiality of only sixteen elements. Of these sixteen, six elements Viz. nitrogen(N), phosphorus(P), potassium(K) as primary nutrients, calcium(Ca), magnesium(Mg) and sulphur(S) are used in large quantities by the plants as secondary nutrients, while seven others viz., zinc(Zn), Iron(Fe), copper(Cu), Manganese(Mn), Boron(B), molybdenum(Moo) and Chloride(CI) are required in relatively smaller quantities and are called micronutrients or minor nutrients. In addition, there are five more nutrients like cobalt(Co), Nickel(Ni), Sodium (Na) , vanadium(Va) and Iodine(I). The mobility of nutrients in the plants is the normal function of the plant in order to meet its growth and development requirement. The mobility of nutrients is grouped into four categories based on their mobility as:

- Highly mobile(N,P,K)
- Moderately mobile(Zn)
- Less mobile(S, Fe, Mn, Cu, Mn, CI) and
- Immobile(Ca & B)

The below table shows the visual symptoms of nutritional disorders in plant leaf:

Table 1: Visual Symptoms of Nutritional Deficiency in plant Leaf

Nutrition	Visual symptom of Nutrition deficiency
Nitrogen	Older leaves mainly look pale green with yellow chlorosis. In advanced stage both young and old leaves will be yellow
Phosphorus	Older leaves with marginal purple pigmentation, brown, lesions, necrosis of leaf, dark green leaf.
Potassium	Yellow chlorosis, necrosis of marginal leaf area is noticed and in severe cases it occurs on both younger and older leaves.
Calcium	Necrosis, curling of necrotic leaf downwards and black coloration could be as in younger leaves and buds.
Magnesium	Older leaves appear pale brown and yellow, interveinal chlorosis, brown black and purple lesions at advanced stage.
Sulphur	It is similar to N deficiency but the young leaves turn faint yellow with interveinal chlorosis yellow.
Iron	Prominent yellow or white interveinal chlorosis, veins green
Zinc	Young leaves with dull (pale) yellow colour, the yellowing will occur between the veins and midvein in upper and middle half of leaf.
Manganese	Young leaves will be yellow, interveinal chlorosis and interveinal lesions.
Copper	Young leaves with transparent white small interveinal lesions and veins white, necrosis of apical leaf and bud growth ceases.
Chloride	Young and older leaves turn pale yellow at periphery and margins all along the serration of leaf.

Molybdenum	Dull to pale yellow in young leaves and chlorosis with undulating surface, oozing older leaves oozing of resins near midrib of leaf could be seen in older leaves.

Even though extensive research is being done on using computer vision in agriculture, the amount of work done in identifying nutrition deficiency in plants is meager. The overuse of fertilizers has become a common phenomenon in field management, which has led to the serious adverse effect on plant growth, soil, air and water. Therefore, to achieve precision management of fertilization and agricultural sustainability, timely and precisely nondestructive diagnosis is necessary.

Literature survey

Kadipa et.al [1] (2020) proposed a method for identifying and classifying nutrition deficiency in black gram plant using deep convolutional neural networks. A dataset consisting of 4,088 leaf images was collected for experimentation. Proposed method identifies and classify six types of deficiencies namely, Ca, Fe, K, Mg, N and P. combined images of old leaf and young leaf were used to identify six nutrition deficiencies. Results showed that combined image produces more information than a single image. Deep pre trained model were used to extract the features from the image automatically. Extracted features from ResNet50 deep pre-trained model are fed into three different classifiers as the input: (1) logistic regression, (2) support vector machine and (3) multilayer perceptron and compared the performance of these models. The multilayer perceptron models achieved superior performance than support vector machine and logistic regression by the accuracy of 88.33 %.

Kadipa et.al [2] (2019) examine the use of various deep convolutional networks with transfer learning to identify nutrients deficiencies in a black gram leaf image. Experiments were conducted with a dataset containing 4,088 images of black gram leaves grown under seven different treatments, i.e., complete nutrient treatment and six nutrient deficiency treatment, including calcium (Ca), iron (Fe), magnesium (Mg), nitrogen (N), potassium (K), and phosphorus (P) deficiencies. Experimental results showed that a deep CNN model ResNet50 was the best among all experimented models with a test accuracy of 65.44% and a F-measure of 66.15%.

Ukrit et. al [3] (2018) proposed a method for identifying nutrition deficiency in black gram plant using convolutional neural networks. A dataset consisting of 3,000 leaf images was collected for experimentation. Proposed method identifies five types of deficiencies namely, Ca, Fe, K, Mg and N. proposed method first divides manually segmented image into small block of size S X S(S=64). Secondly, each block of leaf pixels is fed to a set of convolutional neural networks (CNNs). Then, each CNN is trained specifically for a nutrient deficiency and is utilized to decide if a block is presenting any symptom of the corresponding nutrient deficiency. After these steps, the responses from all CNNs are integrated in a winner-take-all strategy to produce a single response for the block. After the rest of the processes are done, the responses from all blocks are integrated into one using a multi-layer perceptron to produce a final response for the whole leaf. Experimental results show the superiority of the proposed method over trained humans in nutrient deficiency identification.

Basavaraj et. al [4] (2020) designed a deep convolutional neural network (DCNN) framework for automatic recognition and classification of various biotic and abiotic paddy crop stresses using the field images. The pre-trained VGG-16 CNN model was used for the automatic classification of stressed paddy crop images captured during the booting growth stage. The trained models achieve an average accuracy of 92.89% on the held-out dataset, demonstrating the technical feasibility of using the deep learning approach utilizing 30,000 field images of 5 different paddy crop varieties with 12 different stress categories. The proposed work finds applications in designing the decision support systems and mobile applications with interactive UIs for automating the field crop and resource management practices.

Prabira et. al [5] (2020) proposed a convolutional neural network (CNN) based approach for prediction of rice nitrogen deficiency. The pre-trained CNN architecture is modified to improve the classification accuracy with the inclusion of pre-eminent classifier like support vector machine by replacing the last output layer of CNN. In their work six leading deep learning architectures such as ResNet-18, ResNet-50, GoogleNet, AlexNet, VGG-16 and VGG-19 with SVM are used for prediction of nitrogen deficiency with 5790 number image samples. The performance of each classifier is calculated and compared with each other in terms of accuracy, sensitivity, specificity, false positive rate (FPR) and F1 score. The statistical analysis is performed to select the best classification model considering the results of 100 independent simulations. The statistical analysis confirmed the superior performance of ResNet-50+SVM than the other five CNN-based classification models with an accuracy of 99.84%. Also, the accuracy score of CNN classification models is compared with other traditional image classification models such as colour feature + SVM, bag-of-feature, histogram of oriented gradients (HOG)+SVM, local binary patterns (LBP) + SVM, and Gray Level Co-occurrence Matrix (GLCM)+SVM.

Diego et. al [6] (2015) proposed a method for identifying and classifying nutrition deficiency in coffee plant. The proposed system uses a machine learning technique called random forest to automatically classify nutrition deficiency. The input is an RGB image of a coffee leaf. The input image is preprocessed and visual features are extracted by local and global descriptors. The extracted features were used to build a random forest model to classify the nutritional deficiencies of the analyzed coffee leaf. Random forest was used with four models namely local features, global features, combining of both (local and global feature) and combining SIFT local and global feature. The proposed system was tested on 335 images of coffee leaves. Evaluation results showed that global features have better performance compared to local features. The proposed system successfully classified nutrition deficiency of boron, calcium, phosphorous and nitrogen in coffee leaves. Nutritional deficiencies of magnesium, manganese and iron have similar visual symptoms. It is necessary to incorporate better features for representing veins in order to improve the performance of the classification. Additionally, it is necessary to improve the features to detect necrosis on the leaf tip to identify nutritional deficiency of potassium.

Marcelo et. al [7] (2017) in their study proposed a method that uses shape and texture features for identification of nutritional deficiencies of Boron (B), Calcium (Ca), Iron (Fe) and Potassium (K), in images of coffee leaves. Input images are preprocessed and segmented using Otsu's method. Blurred Shape Model (BSM) and Gray-Level Co-occurrence Matrix (GLCM) is applied on resulting images for extracting shape and texture features. These data are used for training supervised KNN, Naïve Bayes and Neural Network classifiers in order to recognize nutritional deficiencies. The experimental results showed that the developed procedure had high accuracy, in the identification of Boron (B) and Iron (Fe) deficiencies and modest results in identifying Potassium (K) and Calcium (Ca) deficiency.

Chitra et. al [8] (2016) proposed a method for identifying nutritional deficiency in citrus tree leaf using image processing technique. Different methods such as threshold, edge detection, region based and clustering technique, are used to identify the spots and wavy lines and the abnormalities in the citrus leaf. The proposed method is the integrated approach of K-means clustering and Kirsch operator which is beneficial for the proper segmentation of the leaf diseases. The diseased spots are identified by clustering where the wavy disorders are divided by the Kirsch operator. The performance has been analyzed with the help of different segmentation methods and the parameters. Both the supervised and unsupervised segmentation technique is employed to detect the effects of climatic and nutritional disorders on the citrus plants leaves. The proposed method showed that results can be improved by combining k-means clustering and kirsch operator.

Leena et. al [9] (2018) proposed a method for identifying macronutrient deficiencies in Maize plant using machine learning. Here, two techniques are used for image segmentation and feature extraction to generate two feature sets from the same image sets. The first technique uses color histogram for image segmentation and feature extraction whereas the alternative method uses K-means clustering for segmentation and textural features extraction. These are then used for classification using different machine learning techniques namely ANN, KNN and SVM. The results reveal that deep network with auto encoders gives the highest accuracy and superior performance for histogram based feature extraction compared to the other classification methods.

Latte et. al [10] (2017) in their study proposed a method based on HSV color model and Rule based approach to identify Nitrogen, Phosphorus and Potassium deficiency in paddy leaf images. Around 400 images were captured considering 60 images in each category. Leaves infected by pathogen were not considered. Captured image war resized using MATLAB tool and the noise in the image is reduced using the median filter. HSV color features are extracted from healthy, nitrogen defective, phosphorous defective and potassium defective categories along with test images. Based on Hue, Saturation and Intensity (HSV) color model, the mean, the minimum, the maximum, and the deviation values are computed for every image in each dataset. Then the minimum of minimum values, and the maximum of maximum values are also computed. Since hue value resulted in inaccurate results compared to saturation and value, average hue, minimum hue and maximum hue and deviation value of all four categories are extracted. Classification is attempted in two stages. The first level is to classify healthy and non-healthy paddy leaves and the second level is to classify unhealthy paddy leaves as nitrogen, phosphorus and potassium defective paddy leaf images. The color features of test image are extracted and compared against database properties. Comparison results are cross-validated against the rules set to find the exact deficiency. The rules are framed based on rigorous experiment. The overall identification accuracy is 95.39%. Proposed work can be extended for other nutrient deficiencies like boron, manganese etc.

Arya et. al. [11] (2018) proposed a method for detecting unhealthy plant leaves using image processing and genetic algorithm. The proposed method uses image processing toolbox for measuring the affected area of disease and to determine the difference in the color of the disease affected area. First, the RGB images of leaves are converted into Hue Saturation Intensity (HSI) color space representation. After the transformation process, only the H component is taken into consideration for further analysis. The next step is to mask and remove the green pixel as they represent the healthy areas of the leaf. After extracting the infected portion of the leaf, the infected region is segmented into a number of patches of equal size using ostu’s method. Segments which are having more than fifty percent of the information are taken into account for further analysis. Color-Co-Occurrence methodology is used for extracting texture features from the selected segment. Texture features like energy, cluster shade, contrast, local homogeneity, and cluster prominence are computed for the Hue (H) content of the image. Finally, genetic algorithms are used for the classification of diseases.

Yuanyuan et. al. [12] (2018) experimented on a method that uses machine vision technology to monitor the dynamic responses of rice leaf morphology and color to nitrogen, phosphorus, and potassium deficiencies. During their experiment, the top four leaves of each plant were scanned every three days, and all images were processed in MATLAB to extract the morphological and color features for dynamic analysis. The mean value and regionprops functions were used to extract the leaf color and morphology features. Mean value function was used to calculate the average value of objects and the regionprops function for the morphological properties of the image. Among the various leaf morphological features, the leaf area provides more comprehensive leaf information that revealed the dynamic nature of leaf extension. The normalized red index was used to describe the dynamic changes of leaf color to NPK deficiency. To identify the leaf responses to NPK deficiencies, chlorotic part of the leaf was segmented using “colorseg” function and chlorosis rate was calculated. Their results showed that different nutrient supplies resulted in various dynamic features which can be used to identify nutrient deficiency at early stages.

Vasudev et al. [13] (2014) proposed a method to identify Nitrogen deficiency in Maize leaf. The main objective is to develop “Nitrate app”. The approach is to turn the manual process to a software application using image processing. Captured image is preprocessed to remove the noises in the source image by using median filter. Nitrogen content in the leaf was estimated, using color features and texture features. Color features Red, Green, Blue, Hue, Saturation and Value components were extracted and analyzed. Texture features entropy, energy, contrast and homogeneity were extracted by calculating Gray level co-occurrence matrix and Nitrogen content of the plant estimated. This estimated value was compared against the values obtained from laboratory tests. System finds the nitrogen content along with report generation that gives information about whether the input leaf is deficient or healthy. It gives a proper suggestion based on the result and generates a report. Use of image processing makes it accurate and error free.

Swapnil et. al. [14] (2013) proposed a method for identification of nitrogen deficiency in the cotton plant by using image processing technique. The proposed method uses two preliminary steps one for histogram analysis and other for leaf area calculation. In case of nitrogen deficient leaf histogram has smaller peak amplitude than that of normal leaf and area of deficient leaf is less than that of normal leaf. Hence by comparing deficient leaf with normal leaf, they were able to identify nitrogen deficiency in the cotton plant.

Prabira et. al [15] (2017) in their study proposed a method for identification of mineral deficiency in rice crop based on SVM classifier using two clustering techniques K-Means & Fuzzy C-Means. The test images are collected from the IRRI, Philippines database. The input images are in RGB (Red, Green and Blue) form. The input image is preprocessed to enhance the quality of image and for noise removal. Unsupervised K-means clustering was used on segmented image to extract 13 different features. The color feature, mean value of each plane is calculated. The shape features like area, perimeter, width, height eccentricity, convex area, area/perimeter, area / convex area are calculated and also, geometric moment value of R plane is calculated. Same similar features were also extracted using fuzzy c-means clustering technique. Supervised learning model SVM was used for classification purpose. The SVM successfully classify the different type of mineral deficient leaf image of the rice crop using extracted features from both k-mean and fuzzy c-means clustering. The accuracy of result in SVM using k-means clustering is 85% and fuzzy c-means is 93%. With respect to the computational time, the time taken to produce the result in SVM using Fuzzy C-Means clustering is better than K-Means clustering. Fuzzy C-Means clustering is more accurate & noise free technique.

Anand et. al [16] (2016) in their work proposed a method for detection of diseases on brinjal leaves. The proposed method uses K means clustering algorithm for segmentation and Neural-network for classification. Method is used to identify leaf spot disease. Different Images of healthy and disease affected brinjal leaves are collected from the dataset. Histogram equalization is performed on the image in order to increase its quality. Resizing of the image is performed in order to maintain uniform size for all the dataset images. After resizing, the RGB color transformation is applied on image. Then K-means clustering algorithm is applied. K-means clustering algorithm partitions the leaf image into clusters. The boundaries of the disease affected images are reduced by applying different masking techniques. Disease attacked clusters is converted to HSI translation model. From HSI model the salient texture features such as angular moment, intensity of covariance and entropy features are extracted and then the features set are divided into training and testing feature set. Artificial Neural Network is used as a training algorithm. Based on the training and testing feature set of the neural network, the recognition is performed.

Amrita et. al [17] (2016) in their work proposed a method for identifying diseases in rice. Proposed system identifies and classifies four diseases namely bacterial blight, blast, brown spot and sheath rot. In preprocessing input images are resized and normalized to remove the effect of outdoor illumination. Normalized RGB image is converted into YCbCr space. By observing different images in YCbCr plane, Cb and Cr range for a diseased part are determined. Next step is to check for the row and column number of the image which satisfies this range and converts those rows and columns pixels to white followed by converting the image into binary and multiply this with the original RGB image, this will result in the segmented image. Features are extracted from the segmented image using color feature extraction and zone wise shape feature extraction. All the extracted features are combined and used as an input to classifiers. Two classifiers namely MDC and k-NN have been applied for the classification of diseases. The overall accuracy of k-NN is 87% and minimum distance classifier is 89%. Accuracy can be improved further by considering texture features.

Sanjay et. al. [18] (2011) proposed an algorithm to measure area of Betel leaf. Area measurement method for Betel leaf is based on image processing technique. The results are then compared with the results from the graphical area measurement technique. Initially, the leaf outline was drawn on a graph paper with 1mm grid size and the leaf area was calculated by counting the number of grids. This value was taken as true value. Then, the original RGB leaf image with reference object was binarized to count the number of pixels using image processing method. A reference object, a one rupee coin, with known area was used to convert pixel count of binarized leaf image into leaf area. This measured area was compared with measured true value and relative error was calculated. The algorithm gave accurate results with least possible relative error.

Muhammad et al. [19] (2016) proposed a method called Measuring Leaf Area using Otsu Segmentation method (LAMOS) to measure the area of the leaf using image processing techniques that automate the grid counting method. For measurement of leaf area, firstly segmentation by Otsu method is applied subsequently, denoising is done by median filter and followed by object recognition, boundary tracing and region filling techniques. The tool that is used is Visual C++ 2010 using C++ and .Net languages. The proposed method was tested on three types of leaves and the results have shown that this method could be used in determining the leaf area with a small relative error.

Madhu Jadon [20] (2018) proposed a method for leaf area estimation based on Hough Transform. Leaves samples were taken from Indian Institute of Pulse Research Center (IIPR), Kanpur. A single leaf and a five rupee coin were placed on a white background paper then Images were taken by digital camera. Leaf was segmented using ostu method in blue color channel rather than gray value because blue color is more sensitive to any kind of the leaves and coin is segmented using circular hough transform. Both the leaf and coin masks were combined by logical OR operation. It is performed in bitwise manner on the binary values of each pixel in the images. In combined mask '1' represents either leaf or coin and '0' represents background pixels and leaf area is estimated using simple mathematical formula based on total number of pixels in leaf and coin mask. Finally estimated leaf area by proposed method compared with the graph paper method to calculate the error rate.

Giritharan et. al. [21] (2016) in their work proposed a predictive system using ANN for Smartphones. The proposed system uses ANN, feed forward back propagation network. The basic principle behind the operation of the proposed system is to take the inputs as various parameters that decide the productivity, process them based on the algorithm provided by ANN, and predict the suitable crop for the land. Also, the system suggests some fertilizers that could be used to improve fertility. It also provides the status of productivity of a particular crop in a particular soil. The proposed system is made as an android application, where the user feeds the input and obtains the result. The Matlab ANN Toolbox is the software domain in which the prediction system is built and then imported to Android platform. Fertilizer suggestion is based on Nitrogen, Phosphor and Potassium. Future work involves building this particular application in the regional languages.

Discussion

This paper reviewed different approach used by researchers to identify nutrition deficiency in plants/crops. Paper reviewed last 10 years work on identifying nutrition deficiency in plants irrespective of plant/crops. All the previous works have either used handcrafted features followed by classical machine leaning models to classify/identify nutrition deficiency or deep learning model to classify/identify nutrition deficiency in plant/crops. Most of the work is done on identifying macro nutrition deficiency and amount of work done on identifying micro and secondary nutrition deficiency is meager. Very few works have identified nutrition deficiency with severity level. Very few works have addressed on identifying nutrition deficiency in early stage.

Conclusion

Even though extensive research is being done on using computer vision in agriculture, the amount of work done in identifying nutrition deficiency in plants is meager. The overuse of fertilizers has become a common phenomenon in field management, which has led to the serious adverse effect on plant growth, soil, air and water. Therefore, timely and precisely nondestructive diagnosis is necessary for precision management of fertilization and agricultural sustainability. There is a need for lots of research to be done on this particular area for efficient fertilizer management and to overcome the adverse effect on the environment.

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