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A NEW INNOVATIVE APPROACH FOR PLANT DISEASE PREDICTION USING FUZZY EXPERT SYSTEM

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Abstract—Agriculture plays a crucial role in the country's economic sector, serving as its cornerstone and contributing over half of the nation's economic demands. The traditional model for predicting plant leaf diseases faces challenges such as low accuracy, low detection rate, and high processing rate. Precision farming aids in the identification of diseases in plants, thereby effectively managing their spread through timely and appropriate treatment. Therefore, the focus of this research is to establish a precise framework for predicting leaf diseases using an adaptive fuzzy expert system. The Adaptive Fuzzy Expert System (AFES) is utilized for the purpose of plant leaf categorization. This paper introduced a new approach to accurately identify plant disease.
Keywords— Fuzzy expert system, plant disease, feature extraction, IOT, Fuzzy Logic (FL) etc.

I. INTRODUCTION

Fuzzy Logic Systems (FLS) generate precise and satisfactory results when presented with incomplete, ambiguous, distorted, or imprecise (fuzzy) input. The FL approach emulates the decision-making process of humans, which encompasses all intermediate possibilities between the binary values of YES and NO. The human brain possesses the capacity to make decisions based on uncertain and ambiguo.us data, whereas computers are limited to processing data with precise judgments. Computers can only comprehend data that is represented by values of either "0" or "1"[1]. In the diagnosis of diseases, the use of computer-based analyses has become an crucial tool, making the development of an effective and essential computer-based system imperative [2]. A system of expertise that employs a fuzzy membership functions collection and rules, rather than Boolean logic, to engage in data analysis is referred to as a fuzzy expert system[3]. The fuzzy expert system finds application in diverse domains where the input variables do not have fixed values. A group of membership functions and rules that are applied to data analysis make up a fuzzy expert system. Fuzzy expert systems have many application areas like agriculture, medical, sports, Environmental management, education and many more. The basic components of Fuzzy Expert system is shown in fig. 1. In fuzzy logic, a continuous membership function takes values in [0,1] where 0 means absolutely false and 1 means absolutely true. This is the opposite of Boolean logic, which takes values in [false] and [true]. [4].

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Vol. 17 No. 02 (2023)

Fig 1 Basic components of Fuzzy Expert System

Crisp variables represent exact values, while fuzzy sets are used to represent the degree of possession of a quality. Fuzzy rules-based systems are sometimes referred to as Fuzzy inference systems (FIS). Fuzzy rules play an important role in fuzzy logic. FIS uses IF-THEN rules that imply the next logical step after the previous logical step [5]. Fuzzification refers to the procedure of transforming the crisp inputs into a fuzzy one. The fuzzy inference engine (also known as the decision making unit) solves the problem of the rule base by performing the inferential operations on the rules. The result of the inferential operations is called the fuzzy output. The defuzzification method is used to convert the fuzzy output to the crisp value, which is the real world output.
Intelligent data analytics is utilized in the agricultural industry to identify diseases in crop or plant images and pinpoint any abnormalities. The integration of the Internet of Things (IoT) into the agricultural sector aims to enhance the use of sensor-based techniques for more effective identification. In recent years, there have been several advancements in agriculture, such as environmental forecasting, automated agricultural development, and precision farming, which have incorporated Artificial Intelligence (AI) and Machine Learning (ML) [26] technologies. Modern farming with automated technique helps to increase the productivity with better quality.

II. LITERATURE SURVEY

Harsimranjit Singh et al. [6] presented a study on fuzzy expert system developed in agriculture. Table 1 shows the various methods used for plant disease detection.

TABLE I: Various methods used for plant disease detection.

Year	**Author**	**Method used**	**Application area**
2021	Bhushan V. Patil et. al.	Deep CNN, IoT platform	Identification of diseased cotton plant
2020	Monalisa Mishra et.al	sine cosine algorithm based rider neural network (SCA based RideNN) in IoT environment	Automated plant disease detection
2017	Siddharth Singh Chouhan et. al.	Bacterial foraging optimization based Radial Basis Function Neural	Automatic identification and classification of plant leaf diseases

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Vol. 17 No. 02 (2023)

		Network (BRBFNN)	
2017	Shanwen Zhang et al.	K-means clustering	Identification of cucumber leaf diseases
2017	Vijai Singh et al.	Genetic algorithm	Identification of diseases from rose, beans, lemon, and banana plant leaves
2017	Tallha Akram et al.	Image processing technique	classification of plant diseases in Real time
2017	Yang Lu et al.	Convolutional neural network	Identification of rice diseases
2017	Monzurul Islam, et. al.	Image Processing, Support vector machine	Disease diagnosis of potato plant
2017	Jiang Lu et. al.	Deep Multiple Instance Learning (DMIL)	Automatic Wheat disease diagnosis
2017	Chit Su Hlaing et.al	scale-invariant feature transform	Tomato plant disease recognition
2017	N. Petrellis	Image Processing	smartphone application for plant disease diagnosis-Grape plant
2016	Raheela Shahzadi et al.	IoT based expert system	Disease prediction based on sensor data on cotton crop and recommendation of pesticides for weed, pest and disease
2016	Iqbaldeep Kaur et al.	Support vector machine and Ant colony algorithm	Identification of plant leaf
2016	Godliver Owomugisha et al	Image processing, Machine learning	Disease diagnosis for Cassava Crop
2012	Philomine Roseline et al	Fuzzy logic, expert system	Controlling and remedy for disease management for the – Finger Millets (Ragi)
2011	H. Al-Hiary et. al	K-means clustering and Neural Networks	Detection and classification of plant leaf disease
2010	Dheeb Al Bashish et al	Image processing, K-means technique,NN	Leaf and stem disease detection

Dhandapani, P. and Varadarajan, A. [23] introduced a method for predicting plant leaf diseases using deep learning. Unlike previous approaches, this method considered multi-channel input by incorporating both leaf and soil images. By acquiring and correlating the features of these images using the Pearson correlation coefficient, the method achieved a higher average accuracy. However, it did not include feature extraction, which could potentially reduce computation overhead and improve performance speed. A machine learning method for plant leaf disease

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prediction and segmentation presented by [24]. The technique involved subtracting the background and segmenting the image to reduce complexity. The classification process utilized a multi-kernel machine learning approach, focusing on the leaves of medicinal plants. This approach achieved high accuracy, but further improvements are required for practical implementation in applications. The severity of the disease was predicted using deep learning with fuzzy logic, which was developed by [25] through the implementation of thresholding. The segmentation process utilized threshold criteria, while the detection of disease severity was determined through fuzzy-based decision-making. However, the method's robustness was not demonstrated through validation. In this paper we introduce a new approach for plant leaf disease prediction using adaptive fuzzy expert system.

III. PROPOSED MODEL

In this work plant leaf disease identification and classification of is performed by using Adaptive fuzzy expert system. The identification of plant diseases from leaf images is crucial for farmers to improve crop productivity by preventing the spread of diseases and enhancing soil quality. This research aims to develop an automated framework for predicting leaf diseases based on the AFES (Automatic Fuzzy Expert System) and integrating IoT (Internet of Things) in agricultural fields. Initially, the leaf images captured by sensors undergo preprocessing to remove artifacts and extract the Region of Interest (RoI). Then, significant features are extracted using the Median Ternary Pattern (MTP), Local Directional Ternary Pattern (LDTP), and Locally Directional and External Patterns. These extracted features are combined to create a feature vector, which is used to obtain accurate disease determination results through the adaptive fuzzy expert system. The block diagram of the proposed model is given by Fig. 2.

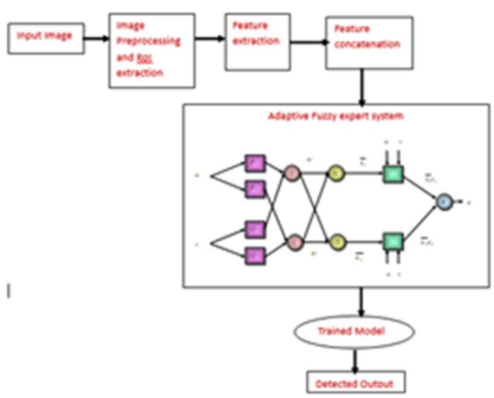

Fig. 2 Block diagram of the proposed model

3.1 Data collection:

The modern agricultural system relies on the collection of data regarding plants and their environmental conditions to accurately track and monitor plant growth. Thus, the aforementioned information is obtained directly from the agricultural field through the utilization of sensors, and subsequently stored within the IoT nodes from which the plant image data is taken and further processed to perform plant leaf disease prediction.

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Vol. 17 No. 02 (2023)

3.2 Image pre-processing and ROI extraction

The collected image undergoes preprocessing and the ROI extraction model to enhance image quality and reduce model training time. Preprocessing of the image involves several procedures, including reshaping, color adjustment, optimization, and feature extraction, all aimed at improving image quality.

3.3 Feature Extraction

The computation overhead can be significantly reduced by utilizing the local directional ternary pattern (LDTP), median ternary pattern (MTP), and the local directional and extremal pattern (LDEP) technique, which extract the essential attributes from the ROI. The extracted features from these methods are combined to create a feature vector. This vector is then inputted into the AFES system for the categorization of plant leaf diseases.

3.4 Disease classification

Disease categorization is carried out through the utilization of the Adaptive Fuzzy Expert System (AFES), wherein the modifiable parameters employed in the fuzzification and de-fuzzification layers are calibrated using the hybrid algorithm. Disease prediction is carried out by employing the Adaptive Fuzzy Expert System (AFES), as illustrated in Fig. 3.

The involvement of experts and the acquisition of knowledge are not essential for disease prediction based on fuzzy logic. In this scenario, the suggested method for predicting plant leaf diseases utilizes if-then rules. The AFES (Artificial Fuzzy Expert System) combines fuzzy rules with Artificial Intelligence (AI) to enhance the efficacy of predictions. Moreover, the AFES reduces errors resulting from data memorization and ensures greater transparency.

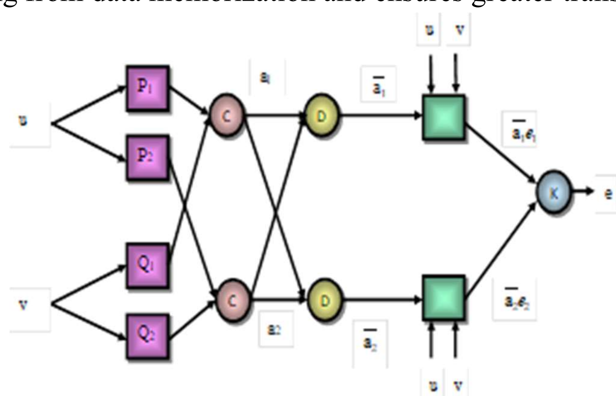

Fig. 3 Architecture of Adaptive Fuzzy Expert System

By optimizing the learning process, the AFES assists in tuning the modifiable parameters in the first and fourth layers, leading to more accurate decision-making with minimal loss.

3.4.1 Fuzzification:

By utilizing adaptive nodes, the fuzzification layer of the AFES calculates the output based on the degree of the membership function for the corresponding input. This is expressed as,

$$A_t^1 = \alpha_{P_t}(u), \qquad t = 1,2 \tag{1}$$

$$A_t^1 = \alpha_{Q_{t-2}}(v), \qquad t = 3,4 \tag{2}$$

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Vol. 17 No. 02 (2023)

where, the linguistic label is notated as P_t, in which $\alpha_{P_t}(u)$, and $\alpha_{Q_{t-2}}(u)$ adopt the membership function, in which the values are obtained through the bell-shaped curve, in which "0" states to the minimum value and "1' denotes to the maximal value and is expressed as,

$$\alpha_{P_t}(u) = \frac{1}{1+\left\{\left(\frac{u-l_t}{n_t}\right)^2\right\}^{mt}} \tag{3}$$

where, the premise parameters are notated as $n_t, m_t\ and\ l_t$ respectively.

3.4.2 Multiplier (C): The fixed nodes in this layer utilize simple multiplication to calculate the product. The resulting product is then expressed as.

$$A_t^2 = a_t = \alpha_{P_t}(u)\alpha_{Q_t}(v) \qquad t = 1,2 \tag{4}$$

here, the term a_t refers to the fire strength of the rule.

3.4.3 Normalization (D):

By employing the process of normalization, this layer estimates the ratios of fire strength that correspond to the node. This estimation is expressed as the summation of the fire strength rule.

$$A_t^3 = \overline{a}_t = \frac{a_t}{a_1 + a_2} \qquad t = 1,2 \tag{5}$$

Thus, the output acquired from this layer represents the normalized fire strengths.

3.4.4 Defuzzification:

The normalized fire strengths are multiplied using the adaptive nodes employed in this layer with the first-order polynomial and are expressed as,

$$A_t^4 = \overline{a}_t e_t = a_t(x_t u + y_t v + z_t) \qquad t = 1,2 \tag{6}$$

here, $x_t, y_t, and\ z_t$ refers to the consequent parameters.

Output: The summation of overall outputs is performed to predict the plant leaf disease and is expressed as

$$A_t^5 = \sum_{t=1}^{2} \overline{a}_t e_t = \frac{\sum_{t=1}^{2} a_t e_t}{a_1 + a_2} \tag{7}$$

Here, the tunable parameters utilized in the fuzzification and the defuzzification layers like $n_t, m_t\ and\ l_t$ and $x_t, y_t\ and\ z_t$ are tuned using the hybrid algorithm for enhancing the performance of the AFES model.

IV. CONCLUSION

To effectively control the spread of leaf diseases, precise farming strongly relies on plant disease prediction. To meet this demand, a plant disease prediction model based on an adaptive fuzzy expert system with IoT capabilities was created. Because it integrates the feature extraction approaches of LDTP, MTP, and LDEP, the model's basis on AFES provides optimal performance. Furthermore, the modifiable parameters used in the fuzzification and de-fuzzification layers are optimised using the proposed hybrid approach, resulting in higher accuracy while minimising the loss function.

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