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Technologies, Methods, and Approaches on Detection System of Plant Pests and Diseases

Devie Rosa Anamisa
Faculty of Engineering
University of Trunojoyo Madura
Bangkalan-Madura, Indonesia
devros_gress@yahoo.com

Muhammad Yusuf
Faculty of Engineering
University of Trunojoyo Madura
Bangkalan-Madura, Indonesia
muhammadyusuf@trunojoyo.ac.id

Wahyudi Agustiono
Faculty of Engineering
University of Trunojoyo Madura
Bangkalan-Madura, Indonesia
wahyudi.agustiono@trunojoyo.ac.id

Mohammad Syarief
Faculty of Engineering
University of Trunojoyo Madura
Bangkalan-Madura, Indonesia
mohammad.syarief@trunojoyo.ac.id

***Abstract*— This research aims to identify the technology, methods, approaches applied in developing plant pest and disease detection systems. For this purpose, it mainly reviews systematically related research on identification, monitoring, detection, and control techniques of plant pests and diseases using a computer or mobile technology. Evidence from the literature shows previous both academia and practitioners have used various technologies, methods and approaches for developing detection system of plant pests and diseases. Some technologies have been applied for the detection system, such as web-based, mobile-based, and internet of things (IoT). Furthermore, the dominant approaches are expert system and deep learning. While backward chaining, forward chaining, fuzzy model, genetic algorithm (GA), K-means clustering, Bayesian networks and incremental learning, Naïve Bayes and Certainty Factors, Convolutional Neural Network, and Decision Tree are the most frequently methods applied in the previous researches. The review also indicated that no single technology or technique is best for developing accurate pest/disease detection system. Instead, the combination of technologies, methods, and approaches resulted in different performance and accuracies. A possible explanation for this is because the systems are used for detecting, controlling and monitoring various plants, such as corn, onion, wheat, rice, mango, flower, and others that are different. This research contributes by providing a reference for technologies, methods, and approaches to the detection system for plant pests and diseases. Also, it adds a way of literature review. This research has implications for researchers as a reference for researching in the computer system, especially for the detection of plant pest and disease research. Hence, this research also extends the body of knowledge of the intelligence system, deep learning, and computer science. For practice, the method references can be used for developing technology for detecting plant pest and disease.**

Keywords—Technologies, Methods, Approaches, Detection system, System, Plant, Pests, and Diseases.

I. INTRODUCTION

This introductory section provides a brief overview of the corn, pest, and disease as well as an intelligent system. This section also the captures research objectives, contributions, implications, and brief structure of this paper. There is a lot of plants growing in Indonesia. Climate conditions, such as temperature and humidity, are important factors for plant growth. However, pests and diseases are one of the challenges for farmers. Unsolved pest and disease can reduce plant production result. Therefore, plant pests and disease detection are one of the important activities to avoid poor production. Researchers have attempted to apply various technologies, methods, strategies that can be used to detect, control, and monitor the plant pests and diseases, including manual and automatic. Farmers and agriculture experts normally have capabilities to detect and identify plant pests and diseases with their knowledge and experience. Literature review also shows there exists various computer-based technologies developed using both mobile or web platform to support the farmers and agricultural experts in pests/diseases monitoring. Research on developing more advanced technologies are continuing to progress by multidisciplinary researchers and experts. There are several methods are employed for pests and diseases detection, i.e. Forward Chaining [1], Fuzzy system [2], K-Means Clustering [3][4], Decision Tree [5][6], Bayesian networks and incremental learning [7], Naïve Bayes and Certainty Factor [8], Naïve Bayes [9], Computer vision and artificial intelligence [10], Deep Convolutional Neural Network [11][12], Fuzzy inference system [13], Convolutional Neural Network (CNN) [14], Fractal Dimension Values and Fuzzy C-Means [15], Deep learning [16][17], Machine learning [18]. Furthermore, there are some applications for detection system of plant pests and diseases using technologies as follows: expert system[1][2][3][4][5][7][8][9][11][13][14][19], mobile system[6][12], computer vision and artificial intelligence[10][20], image processing system[15][16][18][20], and Internet of Things (IoT)[21][22][23]. However, research in this area is still needed, especially from the computer science perspective. This is because of the rapid development of computer technology along with the coming more novel methods in computing. Moreover, the emerging resistance of plant pest/disease combine with the complicated process in monitoring have suggested more works are needed. Therefore, this research aims to identify approaches, methods, and technologies of a detection system for plant pests and diseases. This paper contributes by providing a reference for the detection system of plant pest and disease research. It also provides some guidelines and suggestions for methods in developing a system of plant pests and disease. Therefore, this research has implications for researchers as a reference for researching intelligent systems, especially for the detection of plant pest and disease research. This paper has structures as follows: introduction, related works, research methods, results, and discussion, then the final section is the conclusion and further research.

II. RELATED WORKS

This section discusses associated works and references that focus on Intelligent systems research to detect diseases and pests in plants, including methods, techniques, model, and technologies.

Fig. 1. The Knowledge Base of ESTA [1]

Prasad *et al.* [1] developed an expert system for detecting plant diseases based on user responses to questions related to symptoms. The expert system framework in this study is based on the expert system prologue for animated text (ESTA), where knowledge representation was based on the backward structure or forward chaining. Fig. 1 shows that the rules are placed as decisions and symptoms set in parameters. Furthermore, Huili *et al.* [2] captured plant diseases which are influenced by environmental factors, such as temperature and humidity. In this study, an expert system was developed which consider both factors because of the enormous environmental impact on the spread of diseases in plants.

Symptoms that support or deny the occurrence of the disease and the validity of the diagnosis can also be calculated by the weighted Euclidean distance method. Furthermore, Ghaffari *et al.* [3] pointed out Electronic Nose (EN) and intelligent system approach to detect disease in tomato crops. These approaches are used to carry out proper pattern recognition and mimic human olfactory functions. However, this method requires expensive laboratory facilities and skilled technicians. This study utilized K-Means to increase the distance between clusters in the main component space and produce a classification of plant samples accuracy of 94%. Faithprase *et al.* [4] employed the K-means clustering algorithm for plant pest detection. This research indicated that the proposed method could detect and recognize plant pests in its several positions, sizes, orientations, and shapes using efficient algorithms. It was developed by detecting different variant attribute extractions between pests and their habitat, such as leaves and stems using the K-Mean Clustering method. However, K-mean clustering can only identify plant pests by invariant pest rotation to a 360-degree angle to prove the algorithm useful to detect and recognize plant pests. Furthermore, it was developed with a method of diagnosing active and dynamic plant diseases.

While Bai *et al.* [5] examined a diagnosis system for Tianjin planting pest using multi-branch structure. The system utilized multi-branch for accurate and rapid diagnosis. In a hierarchical structure, knowledge of pest species can be formulated in a decision tree with nodes at various levels. Fig. 2. Indicates the hierarchical structure has more advantages for accurate and fast diagnosis. Singh *et al.* [6] captured mobile phone system for plant diseases detection. It is used as a crowdsourcing approach by collecting data and information from multiple farmers in a region. This system employed a binary decision tree to minimize to get accurate and valid decisions about plant diseases. The method also helps farmers answer the minimum number of questions in the system.

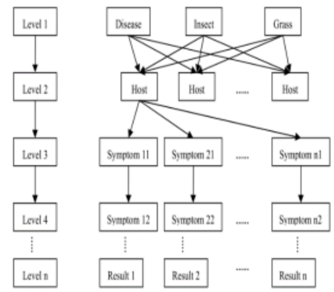

Fig. 2. The hierarchical structure [5]

Moreover, Zhu *et al.* [7] employed Bayesian tissue to represent the relationship between plant symptoms and diseases. Bayesian tissue methods have the disadvantage of improving performance in the detection of plant diseases. However, this method cannot use all signs in detection. It deliberately selects the subset of symptoms that are most relevant to the detection system. Also, it has low time complexity. Syarief *et al.* [8] examined the Bayes theorem method and certainty factor to provide an alternative solution to determine the disease in corn plants, where certainty factor is utilized for classifiers that have varying levels of confidence or weight on each symptom entered. Of the 46 symptoms and 15 types of diseases, calculations using the Bayes theorem produce data on each condition with the highest probability and probability values. Then, it calculates the weight or confidence level of each symptom that causes a particular disease. The results of experiments with these two methods show an accuracy of up to 80%.

In term of research method development, Syarifudin *et al.* [9] examined intelligent systems to detect diseases and pests in corn plants based on android technology. This open-source operating system is free for anyone. It is also a prevalent application currently and one of the most widely used application systems in the world today. Furthermore, an expert system is a solution that can be used to detect corn plants pest and disease. This system would like to adopt expert knowledge to computers to solve problems [10]. Expert systems are useful for helping the community to detect the types of plant diseases and how to overcome the disease problems of corn plants. Hence, they can reduce the errors of farmers in the production of healthy plants. In the expert system, corn disease diagnosis requires a knowledge base containing data facts. Moreover, the inference machines are used to analyze the facts entered by the user to get a conclusion. One classification method used in data mining is the Neural Network (NN) [11]. Furthermore, a Genetic Algorithm (GA) is used to determine the search for parameter values, namely learning rate and momentum on the Neural Network (NN).

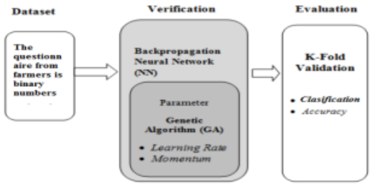

Fig. 3. The Neural Network (NN) Backpropagation Method

TABLE 1. ANALYSIS AND COMPARISON OF NN WITH GA-BASED NN

	Neural Network (NN)	**Neural Network (NN) – Genetic Algorithms (GA)**
Learning rate	0.3	0.62
Momentum	0.9	0.87
Accuracy	96.6%	97.2%

It is employed to obtain a more optimal parameter value and increase the classification accuracy of the model to be applied. The dataset for the model is questionnaire results data from farmers in the form of binary numbers 1 and 0 . It will be used in the Neural Network (NN) model, as shown in Fig. 3. In determining the amount of training cycles, several experiments were conducted to get the best number of training cycles. This value is used for training cycles from 100-1000 with a hidden layer by default in this experiment using the parameter value 0.3 (default) learning rate and 0.2 (default) for momentum. Analysis of testing between the Neural Network model and the Neural Network based on a Genetic Algorithm is shown in Table 1.

The results indicate the model developed by neural networks based on Genetic algorithms produced better accuracy than the neural network without being optimized. High accuracy values are determined by the most optimal parameter values and the optimization results.

Moreover, Picon *et al.* [12] proposed Deep Convolutional Neural Networks (CNNs) as a method for different visual classification tasks. It is applied to detect several plant diseases in real conditions. It is employed to increase the classification accuracy of corn plant pests.

Additionally, the fuzzy model for the detection expert system can provide recommendations on the right type of plant according to the specific soil fertility level. Fuzzy logic is an excellent method to determine an input space into an output space[13]. Fuzzy sets have no precision and membership in fuzzy sets. It is not in the form of true or false logic, but are expressed in degrees. This concept is called Fuzziness, and the theory is called Fuzzy Set Theory. It has ruled as a tool to find out the right type of plant in the soil conditions to be analyzed. Rules are written in the form (IF-THEN) and used in analysis using the fuzzy logic method.

There are several research related to detection of plant pests and diseases, i.e., Liang *et al.* [14] proposed a detection system for plant diseases based on a robust image-based Plant Disease Diagnosis and Severity Estimation Network (PD2SE-Net). This approach can predict disease level, identify species, and categorize disease for plants using deep learning. It has accuracies of 0.91, 0.98, and 0.99 for the disease level prediction, plant disease classification, and plant species identification, serially. Zhou *et al.* [15] described a detection system for rice plant-hopper infestation. The system employed fractal dimension values and fuzzy C-means. Koirala *et al.* [16] proposed a deep learning approach to fruit detection and the production forecasting process. Ferentinos [17] captured deep learning methodologies, particularly convolutional neural network models for plant detection and diagnosis. This approach is using simple leaves images of healthy and diseased plants. Furthermore, 87, 848 images from an open database consist of 25 different plants in a group of 58 distinct classes of plant and disease combinations, including healthy plants, have been used to train the models. The best result is reaching 99.53 success rate for the combination of plant and disease recognition. Barbedo [18] explored the detection of nutrition deficiencies in plants using proximal images and machine learning. Barbedo [20] captured an automatic detection system for plant diseases based on visible image symptoms. This approach has some challenges in the image processing, analysis, and identification. Alajrami and Abu-Naser [19] proposed a detection system for onion plant diseases. The management of knowledge was used in this expert system. Shi *et al.* [21] employed the Internet of Things (IoT) to detect, control, and monitor agricultural disease and insect pest control. It is utilized to detect disease and insect pest information using data processing and mining as well as sensor nodes. Wang *et al.*[22] captured the implementation of association rule mining and fuzzy reasoning information fusion in the controlling plant disease and insect pests. The proposed model is obtaining environment information and the apriori algorithm to implement the real-time monitoring system based on environmental parameters and the presence of diseases and insect pests in the plant. Zhang *et al.* [23] examined the use of IoT to detect, control, and monitor wheat diseases, pests, and weeds. A large number of data will be gathered by IoT terminal to develop a big data system. It is also used to create an intelligent warning system for wheat diseases, pest, and weeds.

III. RESEARCH METHODS

This section captures the methods employed in this literature review. Fig. 4 below illustrates the step by step of research methods and will be explained in more details below. The first step, we searched and collected references about the detection of plant pests and diseases from Science Direct. We chose references in Science Direct as it has good quality. Furthermore, we explored and gathered references from Google scholar as well with the same keywords. The next step was analyzing and identifying the methods, approaches, and technologies which are used in the references. After that, we analysed other exciting points in the references, such as accuracies, performances, results, object plant, limited area research.

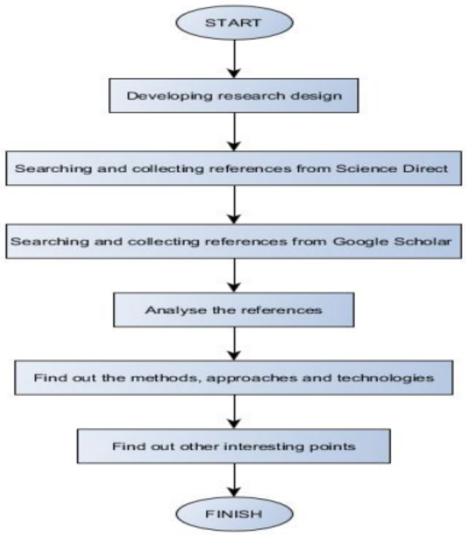

Fig. 4. Step by step literature review method

IV. RESULTS AND DISCUSSIONS

This section will capture, analyze, and discuss some interesting some points based on the related works above.

Our literature review shows that various technologies, methods, and approaches have been used for the detection system of plant pests and diseases. Table 2 below describes the list of methods and technologies for the detection system.

TABLE 2. LIST OF METHODS AND TECHNOLOGIES

References	Methods/ Approaches	Technologies	Advantages/ Limitations/ Accuracy
[1]	Forward Chaining	Expert System	This method has advantages, where the sequence of common features of symptoms can be arranged logically so as to minimize conflict situations, but ESTA has disadvantages, including the emergence of complexity of knowledge-based rules with a number of parameters greater and greater difficulty in verifying rule-based systems in large numbers.
[2]	Fuzzy Systems	Expert System	It is more intuitive and understandable with both positive and negative symptoms. However, the computation time is long. Weighted Euclidean Distance method is employed to measure the comparability.
[3]	K-Means Clustering	Intelligent System	Intelligent system and Statistical were utilized to calculate the data. Electronic Nose has been used to collect the data. Some methods, i.e., Principal Component Analysis (PCA), K-Means clustering, and Fuzzy C-Mean (FCM) clustering and were employed to present the dataset cluster. Moreover, Radial Basis Function (RBF), Learning Vector Quantization (LVQ), and Multi-Layer Perceptron (MLP) based on Artificial Neural Network (ANNs) has been utilized to learn, classify, and categorize the datasets. These methods have produced classification accuracy at 98% for spider mite, 96% for powdery mildew (Oidium Lycopersicum), and 94% for the healthy.
[4]	K-Means clustering	Expert System	The detection process is conducted by extracting different variant attributes between pests and their habitat, i.e., leaves, stems and applying k-means clustering. The next step is correspondence filtering to group and identify plant pests to gain correlation peak values for various datasets to 360-degree angles of invariant pest rotation. The tuning parameters were Y= 0.1, α= 0.0000009; and β= 0.45. Furthermore, it recognizes plant pests in various positions, orientations, shapes, and sizes using efficient algorithms. Therefore, it can calculate the severity of pest. Also, it focuses individually on pest detection at various stages of their lives.
[5]	Decision Tree	Expert System using web	This system is more organized in decision trees with nodes in

			multiple levels compared to dichotomous structures. Therefore, it is faster and more accurate. This system was built using Microsoft SQL Server 2008 database, C#, and ASP.NET. Additionally, this system contains more than 300 species of green plant pests.
[6]	Decision Tree	Mobile System	Mobile crowdsourcing for agricultural advisory systems has the accuracy produced using the Decision Tree method found to vary between 72% and 93%. It shows that accuracy is decreased for diseases identification in higher levels of decision trees. Inaccuracies in the dataset is one of the causes of accuracy decrease. Weka tool is employed in this experiment to process the C4.5 algorithm. It is using the data set to achieve a decision tree. Moreover, the soybean dataset from the UCI repository has been used in this research.
[7]	Bayesian networks and incremental learning	Expert System	The soybean disease data set has been employed for this experiment. It is gathered from the machine learning repository at the University of California. This experiment divided the data into 50 data sets. Additionally, each data set consist of 100 samples. Also, the Markov blanket of diseases has been used in this research.
[8]	Naïve Bayes and Certainty Factor	Expert System	Testing results using the Naive Bayes method and Certainty Factor showed that there was a match between expert systems and expert opinions of 18 out of 30 cases tested. The system produced accuracy at 80% for 15 cases.

[9]	Naïve Bayes	An expert system using Android	The results of testing the Naive Bayes method and Certainty Factor show that all functional requirements are valid with 96% system accuracy and the usability test results are stated to be very good. This experiment utilized 50 data for testing.
[10]		Computer vision and Artificial Intelligence	In identifying the application of computer vision for agriculture, it provides precision production in the form of corn, rice, wheat, soybeans, and barley with the use of GPU (Graphics Processing Unit) and sophisticated artificial intelligence methods. Computer vision systems can provide objective and straightforward sample analysis and produce accurate descriptive data.
[11]	Deep Convolutional Neural Network	Expert System	The CNN Deep Model was trained using open datasets. These datasets contain 39 various classes of plant leaves and background images. This experiment produced a classification accuracy of 96.46%.
[13]	Fuzzy inference system	Expert System	The smart framework to diagnose wheat and cotton plants in Pakistan employed 100 test cases and achieved 99% accuracy. This experiment utilized entropy to measure the disorder of the classification data. This experiment developed 73 rules for decision-making process. Standard Knowledge Discovery in Database (KDD) process has been employed in this research.
[14]	Convolutional Neural Network (CNN)	Expert System	Strong image-based Disease Diagnosis and Plant Level Estimation (PD2SE-Net) networks, which contain residual structures and shuffle units using convolutional neural

			networks (CNN) can improve accuracy and selection of the parameters during the training process that have achieved comprehensive performance very good (overall accuracy of 0.91, 0.98, and 0.99 for estimated disease rates, plant disease classification, and introduction of plant species, respectively) for the existing approach. The data set was Obtained from AI Challenger Global Contest (www.challenger.ai). Additionally, the synthetic dataset published by Hughes and Salathe.
[15]	Fractal Dimension Values and Fuzzy C-Means	Image processing system	This system employed an algorithm based on fractal dimension values and fuzzy C-means (FCM) to detect stress for rice production by Rice Plant Hopper (RPH). The accuracy is 87% for differentiating RPH infestation. Furthermore, the experimental result achieved 63.5% to separate four groups.
[16]	Deep Learning	Image processing system	The deep learning is employed to detect fruit and localization, in supporting the estimation of tree plant loads. This approach is extrapolating the number of tree images with estimates of garden results. Therefore it helps users of deep learning image processing methods. The deep learning is also essential for future applications in fruit detection.
[20]		Digital image processing and computer vision	The digital image processing has implied that superior quality can be captured at a cheaper cost. The digital images will be more reliable media. It also accelerates the development of better accuracy and performance image analysis software.
[17]	Deep Learning		The model training was carried out using

			an open database of 87,848 images, which contained 25 various plants in a different set of 58 combination classes (plants and diseases), including healthy plants and produced a 99.53% of accuracy rate to identify healthy or unhealthy plants.
[12]	Deep convolutional neural networks	Mobile system	Deep Convolutional Neural Networks (CNNs) method has proven successful for various visual classification activities. The trials results of more than 8178 images were collected on two pilot sites in Spain and Germany during 2016. The results indicated an overall increase in balanced accuracy higher than the trials that conducted in Germany
[18]	Machine learning	Image processing system	There is in-depth discussion to address the main challenges of detection and classification methods.
[19]		Expert system	The systems were built using the C Language Integrated Production System (CLIPS) with the Delphi language interface. It was obtained a faster and more accurate diagnosis than the traditional diagnosis.
[21]		Internet of Things (IoT)	The IoT system is very useful for improving the quality of the low technical culture of farmers. The experts can collect diseases, pests, and insects information using data processing and mining, as well as sensor nodes.
[22]	Fuzzy	Internet of Things (IoT)	This system aims to improve the prevention of agricultural level and cure insect pests. It is an intelligent monitoring system for insect pests and farming diseases based on IoT and using fuzzy reasoning inputs. Furthermore, the experimental results show that the recognition level of

			environmental monitoring and recognition rates are 80%.
[23]		Internet of Things (IoT)	The intelligent monitoring system of pests, wheat diseases, and weeds are based on IoT. ZigBee network has been used to relate the terminal sensing tools and the big data technologies by IoT. This technology aims to identify physiology and information about crops environment. This information is produced based on expert experience and knowledge, as well as experimental data.

Some technologies have been applied for the detection system, such as web-based, mobile-based, and internet of things (IoT). Furthermore, the dominant approaches are expert system and deep learning. Moreover, there are some methods used for plant pests and diseases detection, such as backward chaining, forward chaining, fuzzy model, genetic algorithm (GA), k-means clustering, bayesian networks and incremental learning, naïve bayes and certainty factors, convolutional neural network, and decision tree. Those technologies, methods, and approaches also have numerous results, performances, and accuracies.

Moreover, those several technologies, methods and approaches can be used for detecting, controlling and monitoring various plants, such as corn, onion, wheat, rice, mango, flower, and others.

Additionally, there are different perspective between farmers, experts in agriculture, and computer scientist related to the detection of plant pests and diseases. Therefore, they need to collaborate for developing robust technologies, approaches, and methods in term of plant pests and diseases detection. Moreover, theoretical development in intelligent systems is required by adding and combining existing theories from other scientific disciplines such as Computer Science, Information Systems, Medicine, Agriculture, and others.

Furthermore, there are still limited researches on detection system for corn pests and diseases using the intelligent system, deep learning, and Internet of Things (IoT) in Indonesia. Therefore, it can be potential research in this area.

This research has limitations on the references. Additional references might have further insights. Also, other methods of a literature review might produce different results. However, this research can complement the existing research, particularly study on detection system of pests and diseases.

V. CONCLUSIONS AND FUTURE RESEARCH

In this section, we have conclusions from our research, as explained below. In short, this research shows several things, such as effective methods for developing disease detection systems in plants. This paper also describes technological advances that can provide valuable information, especially to farmers.

This paper contributes further by using a new approach for conducting literature reviews. Also, it makes contributions by providing alternative technologies, methods, and approaches for research and development of a detection system for plant pests and diseases.

The summary above illustrates that there are developments both in terms of methods and technology in the detection of diseases and pests in corn plants for effective comparison of methods in decision making.

In the future, it seems interesting to research developing methods in intelligent systems for detecting diseases and pests in corn plants because they are still constrained.

Hence, this research also extends the body of knowledge of Intelligence System, deep learning, and computer science. For practice, the method references can be used for developing technology for detecting plant pests and diseases.

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