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Machine Learning and Deep Learning for Maize Leaf Disease Classification: A Review

Machine Learning and Deep Learning for Maize Leaf Disease Classification: A Review

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Abstract. Image classification of maize disease is an agriculture computer vision application. In general, the application of computer vision uses two methods: machine learning and deep learning. Implementations of machine learning classification cannot stand alone. It needs image processing techniques such as preprocessing, feature extraction, and segmentation. Usually, the features are selected manually. The classification uses k-nearest neighbor, naïve bayes, decision tree, random forest, and support vector machine. On the other side, deep learning is part of machine learning. It is a development of an artificial neural network that performs automatic feature extraction. Deep learning is capable of recognizing large data but requires high-speed computation. This article compare machine learning and deep learning for maize leaf disease classification. There are five research questions: how to get data, how machine learning and deep learning classify images, how the classification result compare both of them and the opportunities & challenges of research on maize leaf disease classification. The number of articles to review was 62, consisting of 18 articles using machine learning, 28 articles applying deep learning, and the rest are supporting articles.

1. Introduction

Humans have certain basic needs, including food. The need for food staples is still a problem, especially for third-world countries, including Indonesia. Data on the 2021 Global Hunger Index (GHI) shows that Indonesia has a hunger index of 18. GHI has decreased considerably compared to 2000, which it had a hunger index of 26.1. Indonesia is in second place after Laos, which has a hunger index of 19.5 [1], [2]. The food is undoubtedly a concern for basic needs problems that must immediately resolve.

Indonesia has food staples: rice and maize. Currently, rice is still the primary choice. However, along with a healthy lifestyle, corn has become an alternative food substitute for rice. Unfortunately, the consumption of maize as food is still relatively small, about 30% compared to animal feed, 58% [3].

Each year, the production of maize has increased. However, Indonesia still has not met its target as a self-sufficient country. Many factors affect Indonesia's failure to achieve it. One of the causes is corn disease. The disease attack all parts of maize, including the leaves, stems, roots, cobs and seeds [3]. To perform manual detection and classification, experts must be precise in handling and preventing. The limited experts, make it difficult for farmers to gain knowledge about disease.

An alternative is images classification through computer vision. Disease classification is carried out from images of plants and recognized through a computer program. Many studies have been carried out for the detection of disease, including machine learning. The steps of machine learning (ML) are preprocessing, segmentation, and feature extraction. In the end, machine learning performs

classification. Image enhancement of raw data and appropriate methods in each step will be support to gain good performance of the classification systems [4]–[6].

In addition to a subfield of machine learning, there has been extensive research using deep learning (DL). It is based on Artificial Neural Network. There are many deep learning methods. However, the most widely used was Convolutional Neural Network (CNN). CNN has become a Deep Learning that is reliable for classification, clustering, segmentation, detection, and localization. Various types of CNN architecture have been tested to improve performance measures and computation time [7]–[10].

This review consists of 18 articles using machine learning and 28 articles using deep learning. The machine learning section; explains the steps for classification using various methods of preprocessing, segmentation, feature extraction, and classification. In comparison, the deep learning section describes the multiple architectures of CNN to perform automatic feature extraction and classification. The discussion also includes the type (public or primary) and amount of data, number of classes, and performance measures obtained in each research.

2. Methodology

Methodology is the plan and justification for the reasearch effort. It entails researching the theories and ideas that underpin the procedures employed in order to create a strategy that is in line with the goals. Figure 1 shows the methodology of the review article.

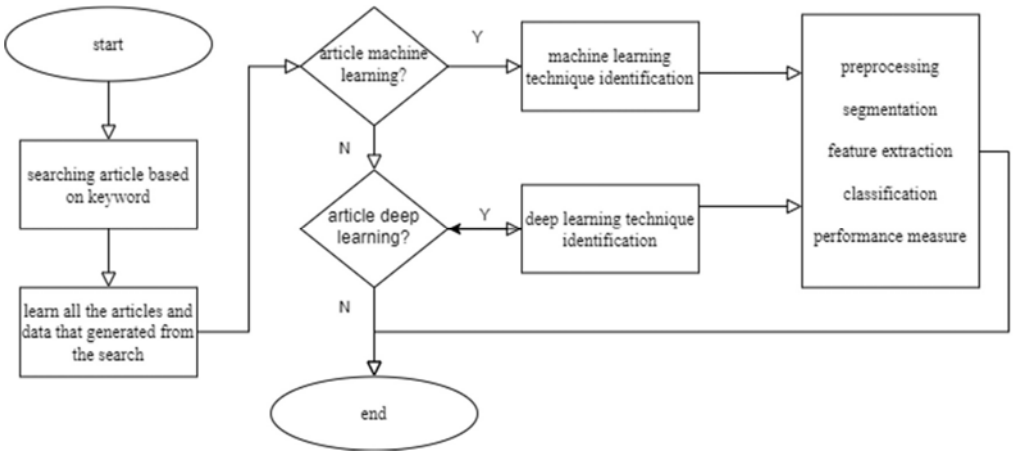

Figure 1. Methodology of review article proposed

The review process begins by searching for articles through scholar.google.com. The papers for review were published between 2016 and 2021. The search process uses the keyword “classification detection of maize leaf disease.” Furthermore, studying is carried out on all articles generated from the search results. If the article contains machine learning or deep learning in the case of disease image classification on corn leaves, it can be saved.

The next step is to identify the techniques in machine learning and deep learning used. The technique consists of preprocessing, segmentation, feature extraction, and classification. It is also important learn about the performance measure of each article.

Next, arrange the questions that must answer during the papers review process. The following are five questions about the classification of disease on maize leaf disease using machine learning and deep learning:

1. How do get data, and what types of disease are found in maize leaf disease?

2. How can machine learning perform image classification?
3. How can deep learning classify maize leaf disease?
4. How do the classification results compare machine learning and deep learning?
5. What are the opportunities and challenges for classifying maize leaf disease?

Table 1 shows the purpose of each research question that has been made.

Table 1. The goal of each research question

Research question	Goal
RQ1. What types of diseases are present in maize leaf disease, and how can data be obtained?	Understanding the types of public or primary data. If the data is public then it can be compared with previous research. If the data is primary then learn the steps of obtaining the data image.
RQ2. How does image classification work using machine learning?	Learning the techniques used for preprocessing, segmentation, feature extraction and classification using machine learning.
RQ3. How is maize leaf disease classified by deep learning?	Understanding the methods utilized for deep learning's preprocessing, segmentation, feature extraction, and classification.
RQ4. How do the categorization outcomes for deep learning and machine learning compare?	ML and DL comparisons to experimental outcomes. It is necessary to compare using the same information.
RQ5. What chances and difficulties exist for categorizing maize leaf disease?	Finding for the novelty of future research

RQ = Research Question

3. Result and Discussion

In this section, we discuss machine learning and deep learning. The technique is to answer the questions in the methodology section. Answers come from the articles.

3.1 Answer the first research question

Image data of maize leaf disease comes from public and local primary data. The number of disease classes varies from two to nine. The most widely used public data for image classification of maize disease is Plantvillage. It contain disease data on crops, including maize. The maize leaf data consists of four classes: healthy, cercospora leaf spot, common rust, northern leaf blight, with each image total 1162, 513, 1192 and 985, respectively [11]. The second data is an image of maize leaves which consists of two classes, healthy and infection, with each class consisting of 2,000 and 2,226 images. The dataset size is 13.05 GB [12]. Various types of disease are:

1. Cercospora leaf spot, common rust, northern leaf blight, healthy leaves [13]–[17].
2. Phaeosphaeria spot, gibberella ear rot, crazy top, gray leaf, common smut, southern rust, Goss's bacterial wilt, and maize eyespot [18].
3. Detect maize leaves that have been infected by fall armyworms [19].
4. Common rust early stage, middle stage, late stage, and healthy stage of common rust disease [20].
5. Healthy, cercospora zeaemaydis tehon and daniels general, cercospora zeaemaydis tehon and daniels serious, puccinia polysora general, puccinia polysora serious, maize curvularia leaf spot fungus general, maize curvularia leaf spot fungus serious, maize dwarf mosaic virus [21].

In number one, the data uses Plantvillage, which is public data. While numbers two to five use local primary data.

3.2 Answer the second research question

Machine learning is a conventional method for performing image classification. Generally, the machine learning steps of completing the classification task consist of four: preprocessing, segmentation, feature extraction, and classification. Figure 2 shows maize disease images classification using machine learning.

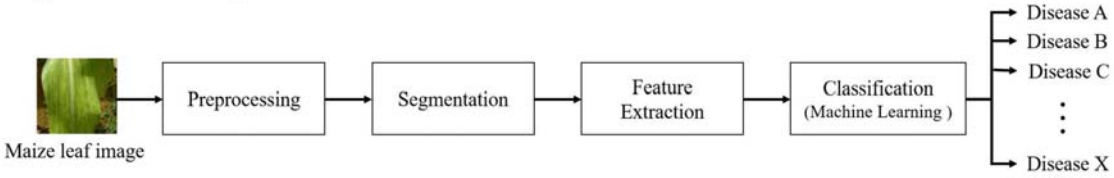

Figure 2. Maize disease image classification using machine learning

3.2.1 Preprocessing. Preprocessing aims to enhance image quality. Preprocessing on maize classification articles include grayscale, resize [4]–[6], histogram equalization [22], LAB Color [23], HSV, noise filtering [24], [25], HSI [26] and noise removal [27].

3.2.2 Segmentation. Segmentation is an image processing technique that divides the parts of the image according to the object intensity. The techniques used for segmentation: edge detection [4], threshold segmentation [26], Segmentation-based Fractal Texture Analysis (SFTA) and Local Ternary Pattern (LTP) [28], texture based segmentation and Simple Linear Iterative Clustering (SILC) [29] and the use of laplacian and canny filters [22].

3.2.3 Feature Extraction. Feature extraction aims to gain image features. These features are useful for classification. Type of features include color [4],[5],[23], shape [4],[5],[27] and texture such as Gray Level Co-Occurrence Matrix [4],[5],[23],[27] are commonly used. In addition, there are also more specific features such as Histogram of Gradients (HOG) [28],[30],[22], RELIEF-F [31], Scale Invariant Feature Transform (SIFT), Speeded Up Robust Features (SURF), and Features from Accelerated Segment Test (FAST) [30],[6].

3.2.4 Classification. Classification is a step for grouping features based on similarity or proximity. Various classical machine learning methods are used for classification such as Naïve Bayes [4],[30],[32], Decision Tree [4],[27],[30],[32], k-Nearest Neighbor [4],[33], Support Vector Machine with all its variants [4]–[6], [23], [25], [26], [29]–[35], Random Forest [4],[30],[32], Deep Forest [4], [36]. Neural Network [22], [24], [25], [32], and Bag of Features [6]. Table 2 shows the maize leaf disease classification using machine learning.

3.3 Answer the third research question

Deep Learning is part of machine learning, with Artificial Neural Network (ANN) as the backbone. If the ANN consists of 3 to 4 layers, deep learning has tens to hundreds of layers. The layers of deep learning consist of feature extraction and classification. Some architecture contains a preprocessing at the beginning of layers. Many deep learning methods that can use supervised and unsupervised learning. This review article focused on the Convolutional Neural network (CNN) for a classification tasks.

3.3.1 *Convolutional Neural Network*. CNN is a deep learning method. LeNet first introduced the concept of CNN in 1998. [38]. However, CNN became widely known in 2012. CNN with AlexNet architecture won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) with an error rate of 16.4%. It beats the machine learning method that has been become the winner for two years consecutively. Alexnet has 25 layers consisting of input, convolutional, ReLU, normalization, max-pooling, fully connected dropout, softmax, and output layers [39]. ILSVRC has more than 14 million images with thousands of classes. In the following years, other CNN architectures emerged as winners

of ILSVRC, including ZFNET, VGG, GoogleNet, ResNet, GoogleNET-V4, and SENet, with errors of 11.7%, 7.3%, 6.7%, 3.6%, 3.1%, and 2.3% respectively [7].

Table 2. Image classification of Maize leaf disease using machine learning.

No.	Methods (Preprocessing, Segmentation, Feature extraction, Classification)	Accuracy	Reference
1	grayscale, resize, edge detection, shape, color, texture, NB, D3, kNN, SVM, RF	76.16% to 80.68%	[4]
2	D3,SVM, LR, kNN,RF	67.5% to 79.25%	[36]
3	LAB color Color, shape, texture GLCM, SVM	85.7%	[37]
4	Segmented Fractal Texture Analysis and local ternary patterns histogram-oriented gradient (HOG), PCA SVM	92.8%-98.7%	[28]
5	SVM	96.7%	[35]
6	RELIEF-F, SVM	87%	[31]
7	SIFT, SURF, ORB, HOG, SVM, D3, RF, NB	-	[30]
8	RGB Channel, CLAHE, GLCM featuresk-NN and SVM	85% to 88%	[33]
9	Image enhancement, grayscale, filter gaussian, binerization, k-means clustering Texture, color, morphology, SVM	95.63%	[5]
10	HSV, noise filtering, 30 features form HSV, SVM , ANN	80-90%	[25]
11	HIS, global threshold, shape features, genetic algorithm, support vector machines with RBF kernel function	96.61%	[26]
12	Grayscale, SURF, Bag of Features, SVM	85%	[6]
13	noises are removed, Optimized Probabilistic Neural Network	95.55%	[24]
14	SVM and LR, CNN	100%	[34]
15	Texture-based Segmentation and Simple Linear Iterative Clustering, SVM	52.5%, 85%	[29]
16	SMOTE for imbalance data, Gradient Boosting, D3 , SVM, RF, NN, NB	92.5%	[32]
17	data noise removal with MNF, Spectral, Shape, and Texture Feature Extraction C 5.0 algorithm	95%	[27]
18	histogram equalization method and, Laplacian and Canny filters Visual features, PCA, NN	90.04%	[22]

Note:
NB= naïve Bayes; D3= Decision Tree, SVM= Support vector machine; k-NN= k Nearest Neighbor; RF = Random Forest; PCA= Principal Component Analysis; LR= Linear Regression; SMOTE= Synthetic Minority Over-sampling Technique. Relief-F = Relief Feature Selection; SIFT= Scale Invariant Feature Selection ; SURF= Speed Up Robust Feature; HSV= Hue Saturation Value ; MNF= Minimum Noise Fraction.

3.3.2 CNN for Maize Disease Classification. Many of CNN architecture are also applied to image classification of maize plant disease. For image classification CNN has architecture such as VGG [13], [19], [20], [40], DenseNet [14], [18], InceptionV3 [15], [19], [41], MobileNet [19], [42], AlexNet [16], [43]–[47], EfficientNet [21], Modify CNN [17], [48]–[54], ResNet [13], [15], [43], [46], [55], SqueezeNet [43], GoogleNet [13], [56], FasterR-CNN, ReTinaNet [57]. For disease detection CNN has YOLO [57]. Another deep learning that used for classification was Autoencoder [48], [49], and LSTM [58]. Figure 3 shows the steps of classifying maize leaf using deep learning. Table 3 shows deep learning method for maize disease classification

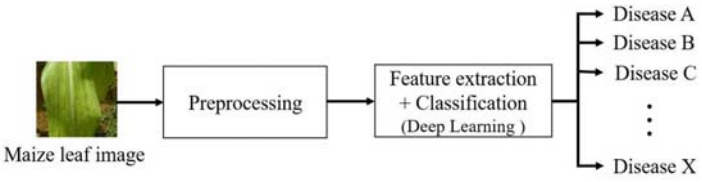

Figure 3. The Steps of Maize Leaf Disease Images Classification using Deep Learning

Table 3. Deep Learning method for maize disease classification

No	Methods (preprocessing and Classification)	Result	Reference
1	GoogLeNet pre-training network, ResNet18, Vgg16, and Vgg19 transfer learning	98.15%	[13]
2	VGG16, VGG19, InceptionV3 and MobileNetV2	99.67% to 100%	[19]
3	histograms; fuzzy decision rules; Otsu threshold, VGG-16	89%	[20]
4	Two-channels combined of VGG+ResNet	98.33%	[40]
5	mobile-DA Net based on DenseNet	98.5% and 95.86 %	[18]
6	CNN DenseNet	98.06%	[14]
7	Inception-v3 / Inception-v4	82,8%, 81%	[41]
8	ResNet50 , Inception V3	97.09%	[15]
9	MobileNet-based convolution neural network	93.23% and 93.75%	[42]
10	AlexNet, ResNet50, SqueezeNet + Bayesian Optimization	97%	[43]
11	AlexNet	72.44%	[44]
12	custom-designed CNN and a pre-trained AlexNet with transfer learning	97.81%.	[45]
13	AlexNet and support vector machine	93.50%	[16]
14	Alexnet , resnet50	94.96%, 98.16%	[46]
15	multi-scale convolutional global pooling neural network AlexNet based	93.28%	[47]
16	EfficientNet	98.52%	[21]
17	enhanced convolutional neural network (ECNN)	-	[48]
18	HIS, regularized deep clustering (RDC) + convolutional autoencoder	95.12%	[49]
19	CNN + BiLSTM	99.02%.	[50]
20	The pre-trained deep CNN consisting dedicated CNN hardware blocks.	88.46%	[51]
21	Convolutional Neural Network and OpenMP implementation	89% to 93%	[52]
22	CNN Adam optimizer	98.78%	[53]
23	CNN	96.53 %	[17]
24	Improved CNN	98%	[54]
25	ResNet50 dan Resnet 152	98.14% and 95.95%	[55]
26	GoogLeNet	98.9%	[56]
27	Faster R-CNN, YOLOv2, and RetinaNet)	95%	[57]
28	long short-term memory (LSTM)	-	[58]

3.4 Answer the fourth research question

The results for maize leaf disease classification need to be compared. But of course, it is difficult to reach if the test parameters vary widely. Comparisons can be made if the same data and the test environment. Table 4 shows the results of the comparison of disease image classification using machine learning and deep learning. Because of the limited article discuss the maize leaf disease for ML and DL simultaneously. For this reason, comparisons are also made on images of other plant disease.

Table 4. Machine learning vs. deep learning

Dataset	Machine learning	Accuracy ML	Deep Learning	Accuracy DL	Reference
Plantvillage, Maize leaf disease (public)	SVM Random Forest Logistic Regression k-NN Decision Tree	79.25% 77.75% 77.5% 74.25% 67.5%	LeNet5 CNN Deep Forest	83.46% 91.25% 96.25%	[36]
CIMMYT Maize kernels, Zimbabwe (local)	Decision Tree AdaBoost k-NN Neural Network Logistic Regression SVM	89.4% 90.9% 93.9% 97% 100% 100%	CNN	98.5% to 100%	[34]
Citrus Leaf Disease (local)	Random Forest Sthocastic Gradient Descent SVM	76.8% 86/5% 87%	VGG19 Inception-V3 VGG16	87.4% 89% 89.5%	[59]
Plantvillage, Tomatoes Leaf disease (public)	k-NN SVM Random Forest	82.1% 91% 82.7%	AlexNet VGG16 ResNet34 EfficientNet-b0 MobileNetV2	92.7% 98.9% 99.7% 98.9% 91.2%	[60]
average		80.41%		93.60%	

Table 4 shows the average accuracy of deep learning is better than machine learning. Machine Learning and deep learning have been implemented in classifying and detecting maize leaf disease. Five items can distinguish it: feature determination, problem-solving ability, processing time, ease of interpretation, and hardware. The following is an explanation of these five factors:

1. Determination of features. In machine learning, the the right features was carried out by experts. If you are unfamiliar with the data being tested, the features are often tested manually. The features that are commonly used in Machine learning are shapes, colors and textures with all their variations. In Deep Learning, the processed image features are included in the algorithm without being determined manually.
2. Approach to solving problems. Machine learning divides the problem into several parts so that they can be solved separately. The task classification is divided into four sections: preprocessing, segmentation, feature extraction, and classification. In the end, they are combined to get the complete result. Whereas Deep Learning algorithms can solve problems without requiring separation of parts..
3. Ease of interpretation. Machine learning algorithms like kNN, Naïve Bayes, Logistic Regression, and Random Forest are easy to understand. In Comparison the Deep Learning Convolutional Neural Network algorithm is difficult to interpret because it consists of many layers and the use of million hyperparameters.
4. Computation processing time. Deep learning requires longer computational time because the data is processed in large quantities, deep layers, and hyperparameter. For example, to do training using MobilenetV2 requires five h, InceptionV3 seven h, VGG16 eight and half h, and VGG19 requires nine h [19]. In another article it is shown the time it takes to do per-epoch training [14].
5. Hardware capabilities. Machine learning can be processed with a conventional CPU, while must processes deep learning with high machine computation because of the large amount of data and classes. The hardware usually has a Graphical Processing Unit (GPU) [14].

3.5 Answer the fifth research question

Today deep learning has shifted machine learning in terms of ease of implementation. This is indicated by the absence of the need for segmentation, feature extraction and even preprocessing if the data obtained is good. Therefore, at this point, it is presented about opportunities particularly on the application of deep learning. The following is an opportunity for further research:

1. Data. Disease of maize can attack leaves, stems, cobs, and seeds of maize. The public data used for the experiment is still limited to Plantvillage with four conditions on maize leaves. So, can do the first novelty using primary data taken from the local area.
2. CNN architecture. The diversity of CNN architectures makes the possibility of novelty. The purpose of architecture modification is to improve performance measures and computation time. Tested various pre-trained CNN networks to determine the appropriate architecture with the test dataset. Then modified the selected pre-trained CNN network, in terms of layer type, a number of layers, hyperparameters tuning, and test variable values such as learning rate, maximal epoch, minibatch_size, and gradient descent optimization type.
3. Visual explanations. Currently, CNN has been developed with the aim of visual explanation, namely Class Activation Mapping (CAM). This method not only focuses on high accuracy rates but also explains to the user the part affected by the disease. This method detection displayed with a heatmap, an explanation through colors in image certain parts. Methods such as Grad-CAM, Grad-CAM++, ScoreCAM can be tested for implementation [61], [62]. None of the articles that have been reviewed, implemented this algorithm yet.

In addition, it is also necessary to think about the challenges faced when applying deep learning methods for classification. In addition to requiring large data, computing also requires high-speed computing. Currently, there is Google Colab which provides space for free, but its use is limited to data implementation using deep learning [36].

4. Conclusion

Maize is the second most important agricultural commodity after rice in Indonesia. Every year, maize productivity will increase expectancy. Disease disorders can reduce productivity. Therefore a system is needed for automatic maize disease image classification and detection.

This article discusses the review of disease classification in maize. Machine learning and Deep Learning with various methods are algorithms used to solve classification problems. Machine learning have 4 steps: preprocessing, segmentation, feature extraction and classification. The classification method for machine learning, such as k-nearest neighbor, and support vector machine are usually used.

Now the deep learning especially CNN become the best alternative. Various of CNN architecture such as Alexnet, VGG, ResNet, GoogleNet is common use for image classification. For the next project, we produces visual explanation using CNN CAM and Grad-GAM. Also, there are a novelty such as the using of primary data, and CNN architecture, and parameter modification.

However, there is a limitation to data processing using deep learning, which requires high-speed computation qualifications and large amount of data. Now there is a google collab that can training deep learning at high computing speed.

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