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COMPARATIVE ANALSYS OF PLANT LEAF DISEASE DETECTION USING GAUSSIAN FUNCTION AND FUZZY C-MEAN CLUSTERING OVER CNN

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Abstract: Plants are very susceptible to the onslaught of diseases; diseases of plants can be distinguished from the buds on the leaves. The disease is visually recognizable as it has a unique color and texture features. But visual recognition has the disadvantage is that it is difficult to recognize the similarity between a disease and a disease other so as to affect the inaccuracy of the identified disease. On research this is where a system that can identify diseases and provide information is a treatment solution in the prevention or treatment of leaf diseases through digital image identification using supervised classification. The imagery will be previously identified through the RGB colour transformation (Red Green Blue) to HSV (Hue Saturation Value), HSV (Hue Saturation Value) to Greyscale, and feature extraction processes texture of GLCM (Gray Level Co-occurrence Matrix). The extraction results of the texture feature are classified over Gaussian Processes and Fuzzy C-Mean using CNN (Convolutional Neural Network) for determining the disease caused by various factors on leaves. The test was conducted with 200 samples of various category of leaves imagery, 160 imagery as training data and 40 imagery as test data. Test results show that the CNN using Gaussian function method has an average percentage of 97.5% accuracy, 95.45% precision, recall 95% and error 5%. While FCM filter produces 95% accuracy, precision 90.83%, recall 90% and error 10%. From the test results, it can be stated that at this research Gaussian Function is a better classifier than Fuzzy C Means.
Keywords: Fuzzy C-Means, Hue Saturation Value, Gray Level Co-occurrence Matrix, Run Length Matrix, Convolutional Neural Network

1. INTRODUCTION

Crops are very susceptible to disease attacks; disease is one of the major factors affecting the quality and quantity of agricultural production globally [3]. Diseases can be recognized from the buds found in the leaves [4]. The disease is visually recognizable because of its unique color and texture. However, visual recognition has the disadvantage of recognizing the similarity between one type of disease and the other disease and thus contributing to the subjectivity and inaccuracy of the identified disease [5]. Several previous research on disease detection in plants has been done. This study discusses the identification of leaves disease with the extraction of color and shape features using HSV (Hue Saturation Value) and Sobel operators which yielded 82.98% success rate [6]. Another study was entitled "Plant Leaf Disease Detection Using Fuzzy C-Means Clustering Algorithm" [7]. In this study we used color feature extraction based on RGB and HSV and texture by GLCM on images, then features were trained and classified with Fuzzy Logic and ANN to determine plant diseases. The results showed that classification with Fuzzy C-Mean achieved 92%. Another study was entitled "Detection of Affected Part of Plant Leaves and Classification of Diseases Using CNN Technique" which discusses the detection of leaf diseases using CNN (Convolutional Neural Network). The research initially used Bilateral Filters to eliminate noise in the imagery. Then, segmentation was performed using the FCM (Fuzzy C-Means) method. Proceeded with the extraction of texture features by GLCM (Gray Level Co-occurrence Matrix) and RLM (Run Length Matrix). And in the final process is classified using CNN (Convolutional Neural Network). The results obtained were accuracy rate 98%, precision rate 96%, error rate 2% and recall rate 97% [8]. Based on the description above, in this study several implementation methods will be implemented. First, the RGB (Red, Green, Blue) image was initially converted to HSV (Hue, Saturation, Value). Then, extraction of texture features was performed using GLCM (Gray Level Co-Occurrence Matrix). The resulting imagery will be classified with CNN (Convolutional Neural Network) and Fuzzy C-Mean (FCM), then compared to determine better classifiers for detecting diseases in leaves automatically. Images of various leaves that have been detected will be provided with information on a remedial solution to overcome or prevent the disease that invades the various categories of plants

2. LITERATURE SURVEY

— **Greyscale imagery**: A greyscale image is an image whose pixel values represent the degree of gray matter intensity of white. Each pixel value in the image greyscale corresponds to its brightness. The greyscale image pixel value will be represented by 8-bit bytes or words, varying the brightness intensity from 0 to

255, "0" is represented as black and "255" are represented as white [9]. Greyscale = ((R * 0.2989) + (G * 0.5870) + (B * 0.1140)).Description: R = Red, G = Green, B = Blue.

- **HSV (Hue Saturation Value):** According to some studies, HSV (Hue Saturation Value) is a colour model best used for image processing and computer vision. Conversion from RGB (Red Green Blue) to HSV (Hue Saturation Value) can be done with the following equation[10]: $r=\frac{R}{255}$, $g=\frac{G}{255}$, $b=\frac{B}{255}$, V = max(r, g, b), Vm = V - min(r, g, b)

$$S=\begin{cases}0 & \text{if } V=0\\ \frac{Vm}{V} & \text{if } V>0\end{cases}$$

$$\text{whereas } H=\begin{cases}0° & \text{if } S=0\\ 60° \times \left(\frac{g-b}{Vm}\right) \bmod 6 & \text{if } V=r\\ 60° \times \left(2+\frac{b-r}{Vm}\right) & \text{if } V=g\\ 60° \times \left(4+\frac{r-g}{Vm}\right) & \text{if } V=b\end{cases}$$

Information: R = Red, G = Green, B = Blue, r = normalized value of R, g = normalized G value, b = normalized B value, H = Hue, S = Saturation, V = Value, Vm = Reduction result of high value with low value on value.

- **GLCM (Gray Level Co-occurrence Matrix):** It was first proposed by Haralick in 1973 with 28 features to explain spatial patterns. GLCM (Gray Level Co-occurrence Matrix) uses texture calculations in the second order. Measurement of textures in the first order using statistical calculations is based on the pixel value of the original image such as variance and does not pay attention to the neighbouring pixel relationship. In the second order, the relationship between the two-pixel pairs of the original image is calculated [11]. The following texture parameter formula used in this study [12]: energy $\sum_{ij} p(i,j)^2$ and entropy $\sum_{ij} p(i,j)\log_2(p(i,j))$.

Information: i = matrix row value, j = matrix column value, p (i, j) = Co-occurrence Matrix row (i) and column (j) element values.

- **Convolutional Neural Network (CNN):** The discovery of CNN (Convolutional Neural Network) was first made by Hubel and Wiesel regarding virtual cortex in the cat's sense of sight. Technically, CNN (Convolutional Neural Network) is an architecture that can be trained and consists of several stages, input (input) and output (output) [16]. Technically, CNN (Convolutional Neural Network) trains and tests each input image through a series of processes, namely the convolutional layer followed by pooling to extract features from consecutive input images. After the pooling operation, the image flattened and then put into the fully connected-layer process to carry out the task classification. Architecture that describes the processes that occur in the method CNN (Convolutional Neural Network) is shown in Figure 1 [17].

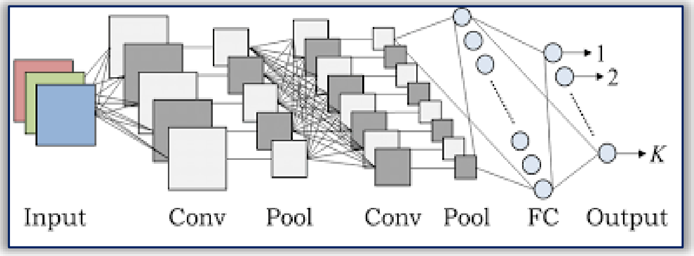

Figure 1: Architecture of CNN

- **Network Neural Convolutional Layer**: This layer uses filters that are also referred to as kernels to find out features, such as the angles in the whole picture. Filters are values of a matrix called weights, which are practiced to detect certain features. Filters move through each section of the image to check if the feature intended to be detected is available. To provide values that indicate how well the features are available, the filter converts the operation [11].
- **Down-sampling**: Down-sampling is useful for speeding up the training process and reducing the amount of memory consumed by the network. The most commonly used down-sampling is max pooling [11].
- **Fully Connected Layers:** Fully Connected Layers of the neural network are processes in which a diflatten input matrix forms a vector and passes through a network of neurons to predict the output probability [11]. This process uses an ANN (Artificial Neural Network) consisting of 2 levels: feed forward [18]:

$$z = \sum_{i,} x_{ij}w_{ij} + b_i \quad \sigma(z)\begin{cases}\text{sigmoid activation} = \frac{1}{(1+e^{z}\ i,j)}\\ \text{softmax activation} = \frac{e^{z\ ij-\max(zj)}}{\sum e^{z\ ij-\max(zj)}\ j}\end{cases}$$

Description: i = matrix row value, j = value matrix, z = amount of heavy input, w = weight, b = bias, σ = activation function.

For the second level is back propagation, the equations used are as follows [19]:

1. $z\delta_{ij} = \frac{1}{n}(a_{ij} - y_{ij})\, w^{T}_{ij}$

2. $a\delta_{ij} = z\delta_{ij} \times \sigma'(z)$
3. $\sigma'(z) = (1 - \sigma(z))$
4. $w_{ij} = w_{ij} - \eta x_{ij}^{T} a\delta_{ij}$
5. $b_{ij} = b_{ij} - \eta \sum a\delta_{ij}$

Description: $z\delta$ = gradient search, $a\delta$ = gradient multiplication result with derivative activation, η = learning rate, w = weight, b = bias, σ' = derivative activation function

— **Gaussian Function:** It is a curve that responds to the equation. The main characteristic of this curve is that it is a good representation of the distribution of random variables in populations, making it useful in statistical calculations as : $f(x) = ae^{-\frac{(a-b)^2}{2e^2}}$. Therefore, the one-dimensional Gaussian filter have an inclination reaction prearranged by $g(x) = \sqrt{\frac{a}{n}}.e^{-ax^2}$ and the frequency response is given by the Fourier transform $\hat{g}(f) = e^{-\frac{n^2 f^2}{a}}$ with f the ordinary frequency [6].

— **Clustering**: Clustering is a process of grouping data into classes or clusters so the data in a cluster has a high degree of similarity between the data one and the other others but very different from the data in other clusters [4]. Clustering is considered as a form of data compression, whereby a large number of samples are converted into quantities small prototype or cluster representation. Depending on the data and applications, there are different types of sizes similarities can be used to identify classes, in which the measure of similarity controls how clusters are formed. Some examples of values can be used as parameters similarities include distance, connectivity and intensity.

— **Fuzzy C-Means:** Fuzzy C-Means is a data clustering technique where available the data points in a cluster are determined by the degree of membership. Determination of cluster point is repeated over and over again until accurate data is obtained by degrees membership. This repetition is based on the minimization of the objective function represents the distance from the data point to the centre of the cluster weighted by the degree of membership. Due to the degree of membership, there can be more than one data point group. This method is a minimization of the objective function to find out plant disease as follows:

$$J_m = \sum_{i=1}^{c} \sum_{j=1}^{n} \left(u_{ij}^{m}\right) \| x_j - v_i \|^2$$

Description: n = Number of iterations, u_{ij}^{m} = Membership Matrix, c = Clusters, uij = Probability that pixel x_j belongs to cluster I, m = Weighting exponent on each fuzzy membership, v_i = Representatives of cluster

Subsequently, the Fuzzy C-Means objective function partitions data into clusters until optimization of the objective function is achieved. For the membership change process or data memberships are used equations and cluster centre updates are used equations following as:

$$v_i = \frac{\sum_{j=1}^{n} u_{ij}^{m} x_j}{\sum_{l=1}^{c} u_{ij}^{m}}.$$

From the issues that have been addressed, the process will be described in detail and research to be done from the data acquisition stage to the acquiring accuracy using the plant disease imagery segmentation stage.

3. PROPOSED METHODOLOGY

Detection and recognition system for leaf imagery developed on this study is modelled on the flowchart shown in Figure 2 which is comprising of two analogies first doing evaluation using CNN with the inculcation of Gaussian Function and another using Fuzzy C-Mean Clustering.

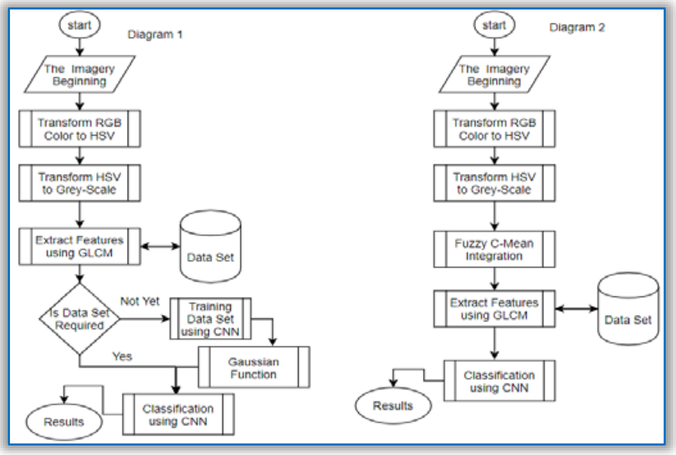

Figure 2: Flowchart Developed Systems with (Diagram 1) Gaussian Function and (Diagram 2) Fuzzy C-Mean via CNN

Color Transformation of RGB to HSV: At this stage the process of color transformation from the initial RGB (Red Green Blue) to HSV (Hue Saturation Value) has been performed. The description of the formula used in the process is as under. The stages of color transformation from RGB (Red Green Blue) to HSV (Hue Saturation Value) are modelled as in Figure 3.

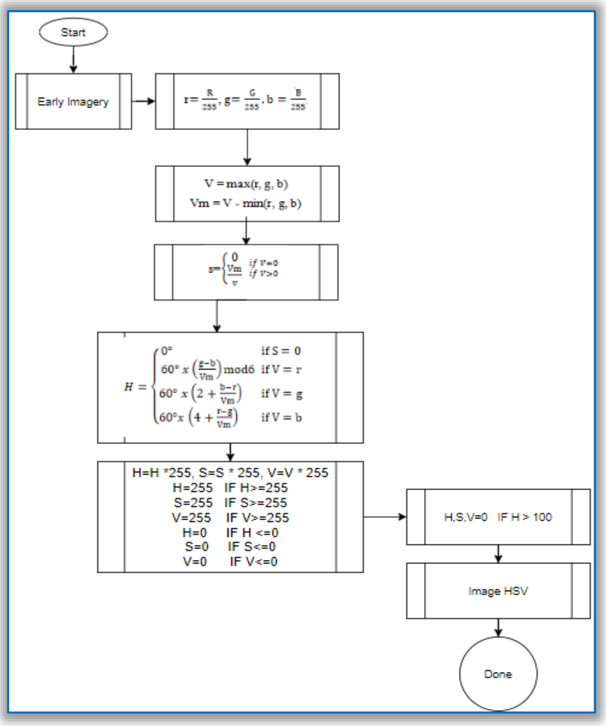

Figure 3: Flowchart RGB Color Transformation Process to HSV

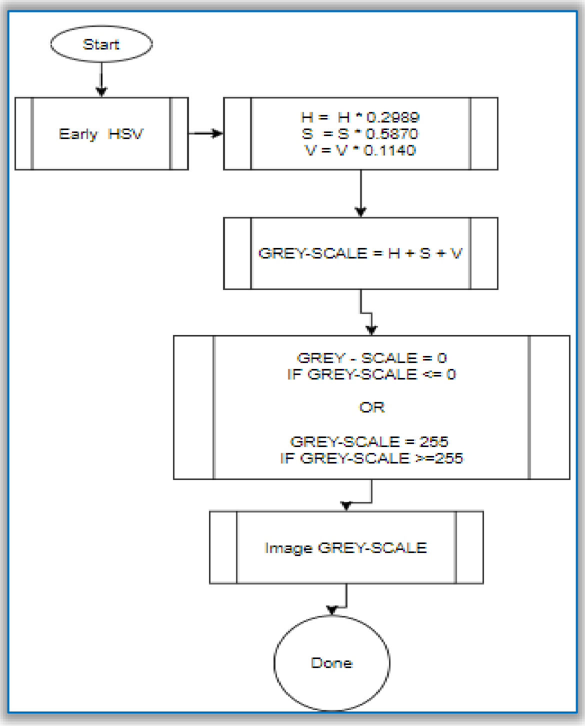

Figure 4: Flowchart HSV Colour Transformation Process to Greyscale

— **Greyscale HSV Color Transformation:** At this stage, the process of transforming HSV (Hue Saturation Value) color into greyscale is performed. This transformation is done so that the process is focused on one layer and the calculation becomes faster. The calculation process is the same as the calculation for converting RGB (Red Green Blue) image to greyscale whose formula description can be seen in sub-section 2.2.1. The processes are modelled by flowchart in Figure 4.

— **Extraction of GLCM Features:** At this stage, the process of extraction of texture features from greyscale imagery with GLCM (Gray Level Co-occurrence Matrix) is performed. Extraction of texture features is done to capture features typical of images, this feature greatly influences the classification of data to determine leaf-borne diseases. Steps to extract GLCM features (Gray Matrix Co-occurrence Level) is modelled in the flowchart in Figure 5.

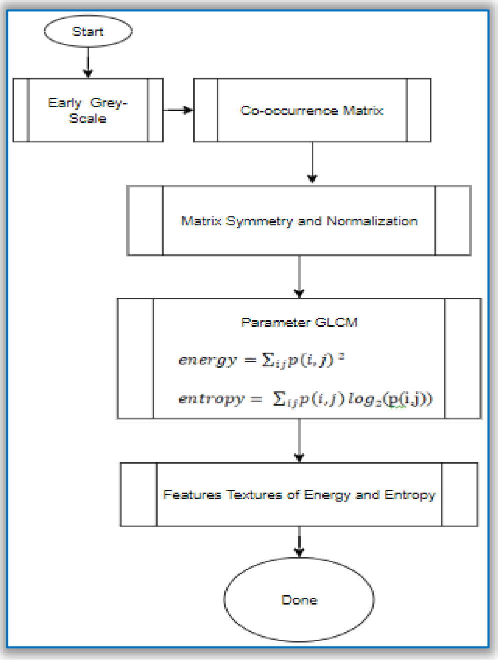

Figure 5: Flowchart Extraction Features of GLCM

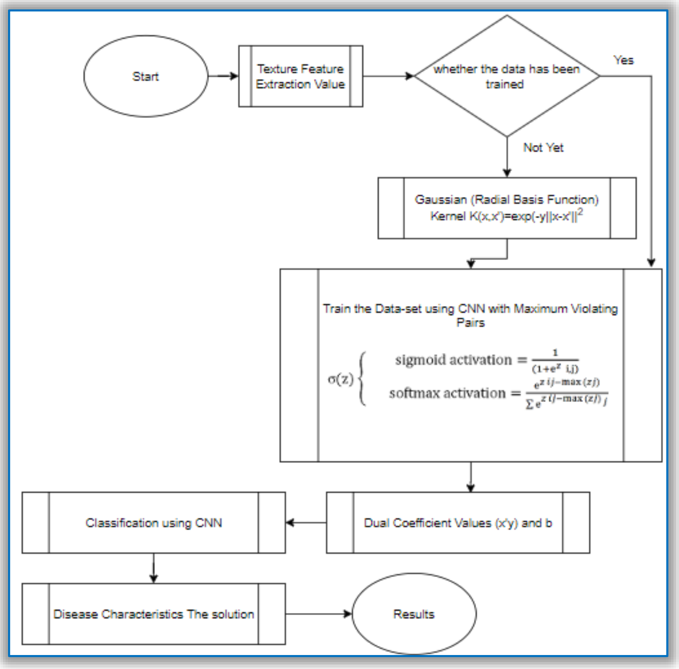

Figure 6: CNN Training and Testing Flowchart using Gaussian Function

- **Training and Testing with GLCM & Gaussian Function:** The GLCM (Gray Level Co-occurrence Matrix) process produces 2 texture feature data which is a float type value. Both feature extraction values are stored in the dataset. The dataset will be used as training data on the Gaussian Function. The stages for training and testing are contained in the flowchart in Figure 6.
- **Training and Testing with CNN:** Extraction of texture features from the GLCM (Gray Level Co-occurrence Matrix) process previously produced (energy and entropy) data in the form of a matrix. The matrices are then converted to images. The image is used as input to the process of convolution and ReLU (Rectified Linear Unit), maxpooling (down sampling) and flatten. These processes are feature extraction processes on the CNN (Convolutional Neural Network) method. The process of feature extraction and features produced by CNN (Convolutional Neural Network) is different from the process of feature extraction and texture features produced by the GLCM (Gray Level Co-occurrence Matrix). The stages of using the CNN (Convolutional Neural Network) method can be modelled with Gaussian Filter for random fluctuations for disease classification using CNN as described in Figure 2 diagram 1. Subsequently, the delegation of algorithm using Fuzzy C-Mean is elaborated as under diagram 2 respectively:

Algorithm:

```
Input
n: number of samples
s: number of features or time points
x: n × s data matrix
c: 1 < c < n, number of clusters
m: m > 1, partition matrix coefficient
e: e > 0, stopping criteria
lmax: lmax > 0, maximum number of iterations
Initialization
Random U(0): c × n partition matrix
l = 1: number of iterations
repeat
Compute the cluster prototypes v
Compute the distance measure D(l) (Eq. (3.3))
Update the partition matrix U
Compute J(l)
if l > 1 then
Compute ΔJ = J(l) − J(l−1)
end if
l = l + 1
until ΔJ < e OR lmax ≤ l
```

4. RESULTS AND DISCUSSION

In this study 200 images of various leaf were used which were divided into four classes of data diseases (healthy leaves, septic leaf spot disease, mosaic and yellow leaf curl), then divided into 160 images as training data and 40 classes as data test. The following are sample data from each disease class in this study shown in Figure 7.

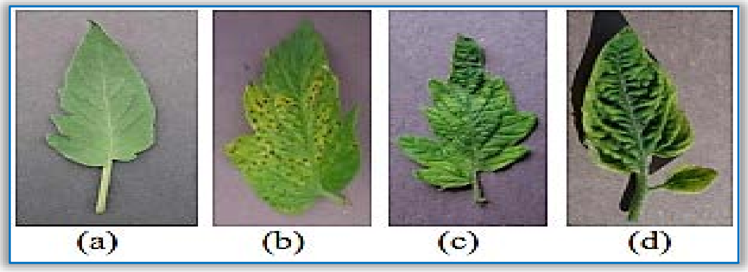

Figure 7: Specimen Images of Leaves

All image data goes through the process of RGB (Red Green Blue) color transformation to HSV (Hue Saturation Value), HSV (Hue Saturation Value) to greyscale and texture feature extraction using GLCM (Gray Level Co-occurrence Matrix). GLCM (Gray Level Co-occurrence Matrix) produces texture feature parameters namely Elongation, Solidity, Smoothness, Uniformity and Entropy. There are two types of texture feature extraction results by GLCM (Gray Level Co-occurrence Matrix). The first is a float value and the second is an image. Texture features of type float value are used for input values in the Fuzzy C - Means, while texture features in the form of images are used for input values in classifications using CNN (Convolutional Neural Network) via Gaussian Function. Table 1 and Table 2 shows the results of the (Convolutional Neural Network) classification process.

Table 1: Matrix Formation using Gaussian Function using GLCM & CNN for Tomato Category of leaves using 12 Specimen Nos. of Samples

Class	Specimen No.	Elongation	Solidity	Smoothness	Uniformity	Entropy
1	1	0.32396	0.98535	0.016108	0.00027477	1.1756
1	2	0.36116	0.98152	0.0081195	0.000074846	0.69659
1	3	0.38998	0.97755	0.0032891	0.000037886	0.44348
1	4	0.35376	0.97566	0.0042707	0.000066272	0.58785
1	5	0.44462	0.97698	0.0020514	0.000023504	0.34214
1	6	0.34284	0.98755	0.0034138	0.000024798	0.34068
1	7	0.44458	0.97964	0.0064523	0.000041495	0.53904
1	8	0.39222	0.98512	0.0079794	0.00014676	0.66975
1	9	0.45693	0.9824	0.0016469	0.000032863	0.33696
1	10	0.58336	0.97683	0.0017901	0.000028251	0.28082
1	11	0.34116	0.98296	0.0013313	0.000031839	0.25026
1	12	0.43387	0.98181	0.0033334	0.00013855	0.49751

Table 2: Matrix Formation using Fuzzy C-Mean (FCM) for Tomato Category of leaves using 12 Specimen Nos. of Samples

Class	Elongation	Solidity	Smoothness	Uniformity	Entropy
1	-0.26768	1.47798	56.6044732	NULL	-1.77918

In Table 1, the results of the testing process carried out on healthy leaves, the average value energy produced by the extraction of texture features for classification CNN is ± 0.25 to 1.17 and the average entropy value that appears is ± 0.51. While in Table 2, the results of the testing process carried out on leaves using FCM affected by tomato disease yellow leaf curl, the average value of the energy produced is ± 1.7 and the average value of entropy is ± 0.14. So, from Table 1 and Table 2, it can be seen that the results of the process of classification of healthy leaves and diseased leaves is influenced by the extraction of texture features (entropy). Texture feature extraction produces unique values. In the same disease, the value and image of the texture feature extraction process resemble each other (the distance between the float values the feature is not so far away and the image of the resulting feature bears resemblance). The testing in this study was carried out on 40 test data images. Results of the testing process is in evaluated using confusion matrix which is a matrix to measure the performance of a classification has 4 variables namely TP (True Positive) means when the system predicts positive and the result is true, TN (True Negative) means when the system predicts negative and the results true, FP (False Positive) means when the system predicts positive and the result is false, FN (False Negative) means when the system predicts negative and the results are wrong. There are some calculations that can be used as a test on the system include from the results of tests conducted on 12 test data images contained in Table 3 then the calculation can be done to determine accuracy, precision, recall and error in each class of disease data. After completing the calculation of accuracy, precision, recall, and error of the four classes of disease data are searched out of the average of the four tests. Calculation results are shown in Table 3 and Table 4.

Table 3: Percentage Value Classification

Disease Detection	TP		FP		TN		FN		Accuracy		Precision		Recall		Error	
	FCM	CNN	FCM	CNN	FCM	CNN	FCM	CNN	FCM	CNN	FCM	CNN	FCM	CNN	FCM	CNN
Healthy	10	10	0	0	30	30	0	0	100%	100%	100%	100%	100%	100%	0%	0%
Septoria Leaf Spot	8	10	0	1	28	29	2	0	90%	97.50%	100%	90.90%	80%	100%	20%	0%
Mosaic	8	8	2	0	28	30	2	2	90%	95%	80%	100%	80%	80%	20%	20%
Yellow Leaf Curl	10	10	0	0	30	30	0	0	95%	97.50%	83.30%	90.90%	100%	100%	0%	0%
Average									95%	97.50%	90.83%	95.45%	90%	95%	10%	5%

Table 4: Average Percentage Value Classification

Type of Testing	Percentage of Test Results FCM	Percentage of Test Results CNN (Gaussian Function)
Average Accuracy	95%	97.50%
Average Precision	90..83%	95.45%
Average Recall	90%	95.00%
Average Error	10%	5.00%

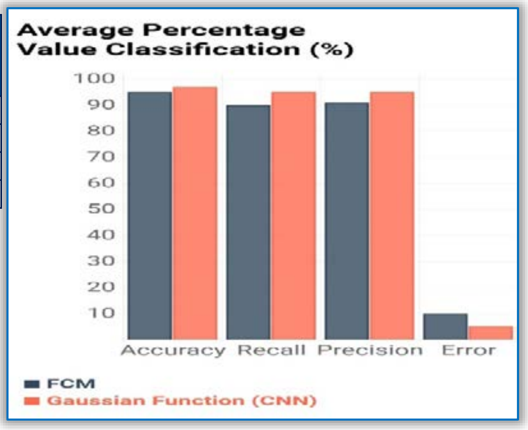

Figure 8: Graph representing comparative analysis based on average percentage value classification

The results shown in Table 4 states that the percentage of CNN (Convolutional Neural Network) using Gaussian Function testing, possess higher average accuracy, precision, recall and also the percentage error value is lower than the results of the FCM (Fuzzy C-Mean) test. The higher the value of accuracy, precision and recall, the better classification done by the system. While the smaller the value of the error, the less likely the system has an error in identifying the disease. By therefore, clearly seen in this study found CNN (Convolutional Neural Network) using Gaussian Function is a better classifier than FCM (Fuzzy C-Mean).

4. CONCLUSION

Based on the results of research conducted on the detection and recognition of plant diseases in leaf images can be concluded as follows:

- The test results are strongly influenced by the extraction of texture features (Elongation, Solidity, Smoothness, Uniformity and Entropy), because the training is only based on texture features only. Therefore, proper pre-processing needs to be done so that it can clarify the texture of the image. The increasingly clear texture can give the characteristics of the disease in an image, so testing the system will be better.
- From 200 images of leaves, 160 images as training data and 40 images as test data, tests using the FCM (Fuzzy C-Means) algorithm to identify diseases suffered by leaves produce an average accuracy of 95%, an average precision of 90.83%, an average recall of 90% and an average error of 10%. While testing with the CNN (Convolutional Neural Network) using Gaussian Function produces better values, the average accuracy is 97.5%, precision is 95.45%, recall is 95% and error is 5%.
- Comparison of results between the FCM (Fuzzy C-Mean) algorithm and CNN (Convolutional Neural Network) found that CNN (Convolutional Neural Network) using Gaussian Function is a classifier that is better used to detect leaf diseases in leaf images in this study.

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