Herb Leaves Recognition Using Combinations of Hu's Moment Variants - Backpropagation Neural Network and 2-D Gabor Filter - Learning Vector Quantization (LVQ)

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***Abstract*— Indonesian people use herbs as an alternative choice to heal many kinds of diseases. The lack of information and knowledge about the merit of herbs will make the recognition turns difficult. The herbs can be recognized by the shape of the leaf. Capturing the leaf as an image allows constructing an automatic system of herbs recognition using image processing. Two steps of image processing for recognition are feature extraction and classification. 2D Gabor filter and Hu's moment invariants are used to feature extraction process. 2-D Gabor Filters are influenced by some vectors that have different values for each feature of leaves. The hu's moment invariants are influenced by the geometric operation. The next step is classification grouping the result of the feature extraction into the right cluster. In this research, two classification methods will be combined with the two feature extraction methods. The first is hu's moment invariants and backpropagation neural network and the second is 2D Gabor filter and Learning Vector Quantization. Each of combination gives the different results. The first combination has recognition rate is about 81.4% and the second combination is about 80%.**

Keywords*— herbs, image processing, feature extraction, classification, leaf recognition

I. Introduction

Herbs are plants which are useful as ingredients in food, medicine, and cosmetic. There are million species of herbs. Indonesia is one of the countries that have so many species of herbs. Indonesian people use herbs as an alternative choice to heal many kinds of diseases. However, this time the Indonesian people have the lack ability to recognizing the herbs. That makes a merit herb recognized as a usual plant. The herbs can be recognized by the shape and color of leaf [1]. The research using the color of leaf to recognize an herb has some limitations because it is depended on imaging conditions [2].

The various features in the bone leaf have different features saving some information to recognize the herb species. So, it will help to design a system using image processing which is able to recognize kind of herbs automatically. There are two processes in recognition using image processing. The first step is feature extraction aimed to take some information from an image. Some of the methods usually used to extract featuring image are 2-D Gabor Filter and Hu's moment invariants. 2-D Gabor Filters are influenced of some vectors that have different values for each feature of leaves. The hu's moment invariants are influenced by geometric operation in image processing. The second step is classification. This process will match the data from feature extraction result with the data in the database made before.

In the previous research, feature extraction methods were combined with classification methods. The result of combining 2-D Gabor Filters and one of classification method that is Learning Vector Quantization could recognize palm print and face expression well [3][4]. Besides that, another classification method often used to recognize an image is backpropagation which is one type of Artificial Neural Network method [5][6][7]. Herb leaf recognition using backpropagation implemented with canny method for feature extraction explains that feature extraction has to be improved, so backpropagation method must be combined with appropriate feature extraction method [8]. In this research, a system using two combinations of feature extraction and classification methods will be designed to recognize the species of herbs based on the shape of leaves. The first combination is 2D Gabor Filter and LVQ. The second is Hu's moment invariants and Back propagation Neural Network. The system will process leaf images and decide what the species of the herb is.

II. METHODOLOGY

A. Feature Extraction

Feature extraction is aimed to get important information from the shape of leaves. The result of feature extraction is a weight value or feature vector value. Each of leaf will have different features assigned with the variation of vector values. In this research, two feature extraction methods will be used. Those are Hu's Moment Invariants and 2D Gabor Filter.

1) Hu's Moment Invariants

The first feature extraction method is Hu's moment invariant using seven geometric image conditions. Seven invariants will be obtained by image moment values. An image moment value can be calculated using the following equation [9]:

$$m_{pq} = \sum_x \sum_y x^p y^q f(x,y), \quad p,q = 0,1,2,... \qquad (1)$$

with,

m_{pq} = digital image moment
p, q = order of the moment
f = value of color image intensity
x, y = coordinates of a pixel

The result of image moment calculation is image moment values in some order. Central coordinate of an image is calculated by some input of order moment values that are 00, 01, and 10. The next step calculates the central coordinate value using the following equation:

$$\bar{x} = \frac{m_{10}}{m_{00}} \qquad \bar{y} = \frac{m_{01}}{m_{00}} \qquad (2)$$

Central coordinate of an image must be calculated from central moment to obtain the invariant moment value toward the rotation. The central moment can be determined as a discrete form using the following equation:

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y) \quad p,q = 0,1,2,... \qquad (3)$$

with

μ = central moment
$\bar{x}, \bar{y}$ = central coordinate of image

The moment will be normalized using Equation (4), so the central moment will obtain the invariant value toward the scale.

$$\eta_{pq} = \frac{\mu_{pq}}{\mu^{\gamma}_{00}}, \ \gamma = \frac{p+q+2}{2}, \quad p+q = 2,3,.. \qquad (4)$$

Based on the value of normalization, seven invariants of Hu's moment can be expressed by seven formulas, those are:

$$\phi_1 = \eta_{20} + \eta_{02} \qquad (5)$$

$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta^2_{11} \qquad (6)$$

$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2 \qquad (7)$$

$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \qquad (8)$$

$$\phi_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] \qquad (9)$$

$$\phi_6 = (\eta_{20} - \eta_{02})\left[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \qquad (10)$$

$$\phi_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})\left[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2\right] + (3\eta_{21} - \eta_{30})(\eta_{21} + \eta_{03})\left[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2\right] \qquad (11)$$

2) 2-D Gabor Filter

The second feature extraction 2-D Gabor Filter worked as bypass filter to distribute local spatial frequency reaching the optimal resolution not only in frequency domain but also in the spatial domain. It can be represented as a complex sinusoidal waveform modulated by Gaussian function. The basic function of 2D Gabor filter in spatial domain can be expressed as [10]:

$$g(x,y,\theta,u,\sigma) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{x^2+y^2}{2\sigma^2}\right] \exp[2\pi i(ux\cos\theta + uy\sin\theta)] \qquad (12)$$

With,

$i = \sqrt{-1}$
u = frequency of sinusoidal waveform
θ = control orientation of Gabor function
σ = deviation standard of *Gausian Envelope*
x,y = coordinates of Gabor filter

Equation (13) composed by two formulas that are a Gaussian envelope and a complex sinusoidal waveform. Gaussian function can be defined using the formula:

$$g(x,y) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{x^2+y^2}{2\sigma^2}\right] \qquad (13)$$

Whereas, sinusoidal waveform complex function can be defined using the formula:

$$s(x,y) = \exp[2\pi i(u\,x\cos\theta) + (u\,y\sin\theta)] \qquad (14)$$

Based on Equation (14), two different parts of functions can be explained as Real function (Equation (15)) and an Imaginary function (Equation (16)). There are two functions expressed the each of function:

$$\mathrm{Re}(s(x,y)) = \cos(2\pi(u\,x\cos\theta) + (u\,y\sin\theta)) \qquad (15)$$

$$\mathrm{Im}(s(x,y)) = \sin(2\pi(u\,x\cos\theta) + (u\,y\sin\theta)) \qquad (16)$$

Selecting frequency and orientation in different values can cause the function generating a filter. 2-D Gabor filter used to make a spatial filter. Each filter consists of a Real part and an Imaginary part. One level combination of frequency and orientation will give an output resulted by modulation filtering counted by average of all pixel convolution values from Real mask filter and Imaginary mask filter (Equation (17))[11].

$$Output = \sqrt{R_{ave}^2 + I_{ave}^2} \quad (17)$$

R_{ave} is the result of convolution value from leaf image with Real mask filter. I_{ave} is the result of convolution value from leaf image with Imaginer mask filter. From the Equation (6), the pair of the complex filter in one level frequency will extract the feature from an herb leaf image. 2-D Gabor filter will extract the feature successfully if the θ and u values are selected appropriately [5].

B. *Classification*

Feature extraction processes will give some different values for each feature as an input to classification processes. One of classification algorithm used Artificial Neural Network will design a network for learning and testing process. In this research, two algorithms of ANN will be used. Those are Backpropagation and Learning Vector Quantization

1) *Backpropagation Neural Network*

Backpropagation is one of Artificial Neural Network algorithm that gives a solution to learning problem using minimization of the error function in weight space. The method minimizing the error function is gradient descent. All the weights in the network are used by this method to calculate the gradient of a loss function. Continuity and differentiability of error function is required by this computation method of the gradient at each iteration step. Because of the composite function and the error function produced by interconnected perceptron is discontinuous. Obviously, a kind of activation function other than the step function used in perceptron is needed. Backpropagation is usually considered to be a supervised learning method because requires a known desired output for each input value in order to calculate the loss function gradient. Backpropagation has the possibility of implementing the chain rule to iteratively compute gradients for each layer as a generalization of the delta rule to multilayer feed forward networks. Artificial neurons (or "nodes") using differentiable activation function that required by backpropagation [5][12].

2) *Learning Vector Quantization (lvq)*

In this research one of ANN algorithm used is LVQ. The algorithm will search the right weight values and will make a group of input vector values based on the cluster initialized before. The steps of LVQ algorithm are [3]:

1. Initialize :
   a. Initial weight of input variable j to cluster i: Wij, with i=1,2,……,cluster (K) and j=1,2,,….., variable (m).
   b. The maximum number of iteration: *epoh* (*MaxEpoh*)
   c. Learning rate parameter : *learning rate* (α) = 0,01 (*default*)
   d. The minimum learning rate allowed : min α
2. Put in:
   a. Input data : x_{ij} with i = 1, 2, …, number of data (n) and j = 1, 2, …, variable (m)
   b. Target of cluster : Tk, with k = 1, 2, …, cluster
3. Initialize the first condition
   a. Epoh (iteration) = 0
4. Do if : iteration is less than or equal to the maximum number of iteration (*Epoh* ≤ *MaxEpoh*) and *mean square error* is less than the *goal* (mse <*goal*)
   a. Iteration = iteration + 1
   b. Do for i = 1 until n
      1. Calculate the value of *J*, so $\|X_{ij} - W_{ij}\|$ can be minimum (expressed as C_j)
      2. Repair the weight of W_{ij} with the following rule :
         a. If T = C_j than : $W_{ij}(new) = W_{ij}(old) + \alpha (X_{ij} - W_{ij}(old))$
         b. If T ≠ C_j than : $W_{ij}(new) = W_{ij}(old) - \alpha (X_{ij} - W_{ij}(old))$
   c. Decrease the value of learning rate α

C. *Simulation Setup*

The system design consists of two processes; those are training processes and testing processes. The images used for two processes are different. Training images are the images saved in the database and used to test the system. If the system gives the better result than the testing process can be done. The testing images are the images used as new input for the system. Training processes have several processes those are preprocessing image, feature extraction process, and the process of training ANN methods for classification. In the process of classification will obtain a database of weight values or feature vectors. This feature vector will be used for the recognition in the testing process. At the testing processes, there are several processes for the leaf images to be recognized. These processes are the pre-processing process, feature extraction process, and recogniton process. The results are the leaves images will be recognized successfully or unsuccessfully. Accuration of recognition process can be calculated using the following equation

$$P = \frac{\sum successful\_recogniton}{\sum total\_testing\_image} x100\% \quad (18)$$

III. Result and Discussion

The recognition of herb leaves will be discussed using two combinations of feature extraction and classification method. The two combinations are 2D Gabor filter - Learning Vector Quantization and Hu's moment invariants-backpropagation neural network.

A. Hu's moment invariants - Backpropagation Neural Network Implementation

In the second implementation stage, the feature extraction process uses seven Hu moment invariants. They have invariant values for geometric image operations that is translation, scale, rotation, and position of the inverse (mirror). The data tested are data which had been taken from the testing data and each image is made into seven kinds of positions, namely:

1. Initial position

This initial position is the first position of the image used as a benchmark. This position has not experienced a translation, rotation or anything else. Fig. 1 shows the initial position of the image used.

Fig. 1. Initial image position

2. Translation

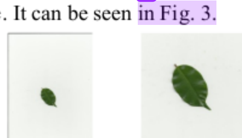
This position is a position that the image object has moved or shift from the initial position. Fig. 2 depicts initial image and the result of using translation.

(a) (b)

Fig. 2. (a) Initial image position (b) Translation image position

3. Scale

In the scale position testing, the scale used is only for enlarging the position of the object. The result of using scale is a larger image. It can be seen in Fig. 3.



(a) (b)

Fig. 3. (a) Initial image position (b) Scale image position

4. Rotation of 90°

This position represents the position of the image that has been rotated 90° to the right. Fig. 4 depicts an example of both initial image and its 90° rotation

(a) (b)

Fig. 4. (a) Initial image position (b) 90° rotation image position

5. Rotation of 180°

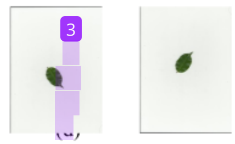
This position represents the position of the image that has been rotated 180° to the right. An example of 180^0 rotation result is depicted in Fig. 5.

(a) (b)

Fig. 5. (a) Initial image position (b) 180° rotation image position

6. Vertical flip

This position is the vertical position of the inverse (mirror). Fig. 6 shows the initial image and changing position after the vertical flip is implemented.



(a) (b)

Fig. 6. (a) Initial image position (b) Vertical flip image position

7. Horizontal flip

This position is a horizontal position of the opposite (mirror). Fig. 7 illustrates the last position of image using horizontal flip.

(a) (b)

Fig. 7. (a) Initial image position (b) Horizontal flip image position

There is one of the test values of seven Hu's moment invariants against banyan leaf. For these values can be depicted in Table 1

TABLE I. THE RESULT OF SEVEN INVARIANTS MOMENT FOR BANYAN LEAF

Position	The values of seven invariant moments of Hu							Detected
	1	2	3	4	5	6	7	
Initial Position	1,75	7,46	13,70	20,45	38,26	24,60	37,67	Banyan Leaf
Translation	1,75	7,46	14,16	19,40	38,91	23,45	36,19	Banyan Leaf
Scale	1,77	8,53	16,11	18,58	36,29	24,02	36,42	Banyan Leaf
Rotation of 90	1,75	7,46	13,70	20,45	38,26	24,60	37,67	Banyan Leaf
Rotation of 180	1,75	7,46	13,70	20,45	38,26	24,60	37,67	Banyan Leaf
Vertical Flip	1,75	7,46	13,70	20,45	38,26	24,60	37,80	Banyan Leaf
Horizontal Flip	1,75	7,46	13,70	20,45	38,26	24,60	37,80	Banyan Leaf

From the above testing results, it can be seen that the extraction of the seven invariant features of Hu's moment is very sensitive to noise especially in the translational position and scale. The seven invariant values of the Hu's moment at the translational and scale positions have different values than the seven Hu's moment invariants at the initial position, but they are not much different and still recognizable during the recognition process. Thus the seven invariant values of different Hu's moments can be said to be within tolerable limits and they do not affect the final outcome of the classification. The thirty pieces of data were trained and tested with previous training results. In the inner data test, the correctly recognized data is thirty and a number of the training data is thirty. The percentage of introduction from the training data test is 100%.

In the data tested, as many as 150 pieces of testing data will be tested in the recognition process where the results of recognition obtained from this recognition system in accordance with the type of leaf image that it has been trained. The testing data had been recognized correctly, there are 126 data and the total testing data are 150. Then the accuration percentage of the test is 83.7%. Banyan leaf, *Keji Beling* leaf, *mengkudu* leaf, *salam* leaf and soursop leaf have the lowest accuration percentage, that is 80%. For *Binahong* leaf, *Jarak* leaf, *Laos* leaf, and *Sirih* leaf have 86% percentage. The last leaf of Papaya has the highest accuration, that is 93%. The average of accuration percentage for all results is 84.1%. This indicates that the system of recognition that has been designed is going well according to the expectations of system design.

B. 2D Gabor Filter - Learning Vector Quantization Implementation

2D Gabor filter is used to extract a feature from a normalized image. The result is a vector of the feature had 16 variations. The variations consist of each vector element of feature obtained from four level value of frequency u that are 2,3,4,5 and values of orientation θ that are 45°, 90°, 135°, 180°. The vector of feature can be recognized if the value is close to the vector feature values and has a pattern that almost resembles a training image vector. In this research, the species of herbs used are 15 herbs. The training image is about 4 for each species of herbs. So, the number of herbs leaves for training image is about 60 leaves. Table 2 shows the result of feature vector values calculation of *Bluntas* leaf.

TABLE II. VALUES OF VECTOR FEATURE FROM BLUNTAS LEAF

Vector to	Beluntas 1	Beluntas 2	Beluntas 3	Beluntas 4
1	0.2387	0.2278	0.1950	0.2091
2	0.0771	0.0735	0.0710	0.0817
3	0.1886	0.1933	0.1815	0.1782
4	0.0908	0.0881	0.0852	0.0911
5	0.2016	0.2161	0.2081	0.1679
6	0.6318	0.6119	0.6407	0.5806
7	0.0710	0.0739	0.0716	0.0705
8	0.1335	0.1415	0.1422	0.1271
9	0.2379	0.2283	0.1963	0.2072
10	0.0776	0.0744	0.0745	0.0737
11	0.1891	0.1931	0.1796	0.1841
12	0.0879	0.0888	0.0865	0.0951
13	0.1373	0.1382	0.1392	0.1355
14	0.6302	0.6123	0.6406	0.5819
15	0.1605	0.1621	0.1501	0.1609
16	0.0708	0.0688	0.0683	0.0797

The feature or weighted vector is a unique number of each image that has gone through the feature extraction process. From Table 1, it can be concluded that the values of the feature vector of the training image are between 0 and 1. The values showing the feature vector of the n^{th} vector has similarity with the other training image if it has the same vector number.

Artificial Neural Network LVQ is used to classify each feature vector of herbs leaves used in the system. The result of the correctly feature vector classification is the leaf can be recognized as an herbs species appropriately. The image of herbs leaves stored in the database is the training image. The training processes are done to search the best network performance shown by minimum MSE (Mean Squared Error) value. Learning rate for training process is 0,01 or default. Training network to search the best one will be stopped if the target value and maximum iteration has been achieved. From all of the network training process, only the best network will be used to the recognition process. The result of training process can be depicted in Table 3

TABLE III. THE RESULT OF SEVEN INVARIANTS MOMENT OF BANYAN LEAF

No	Name	Iterations number	Hidden neurons	*Goal*	Duration (s)	MSE
1	net1	250	200	0.001	223	0.0267
2	net2	250	400	0.001	474	0.0267
3	net3	250	800	0.001	990	0.0267
4	net4	500	200	0.001	393	0.0089
5	net5	500	400	0.001	1014	0.0244
6	net6	500	800	0.001	1137	0.0222
7	net7	1000	200	0.001	717	0.0222
8	net8	1000	400	0.001	1502	0.0222
9	net9	1000	800	0.001	2248	0.0222

Table 2 shows the network training results using 15 species of herbs are in the net4 with MSE value is 0.0089 and 393 seconds training duration or about 6 minutes 33 seconds. Net4 training iteration is about 500 looping and the hidden neurons used is about 200 neurons. From the values of iteration, hidden layer, and the duration, it can be concluded that the greater the number of iterations and the hidden neurons used, the longer the duration of the training will be. The time is longer because of the larger iterations and the hidden neurons will make the calculation more complicated.

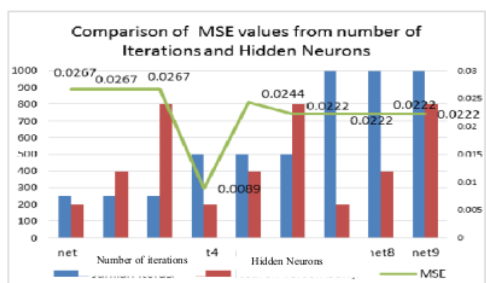


Fig. 8. Comparion of MSE values from number of iteration and hidden neuron

Fig. 8 illustrates the comparison between the number of iterations within hidden neurons and the network performance or MSE having no fixed pattern. This happens because the

Artificial Neural Network does not have a definite theory for calculating and searching the number of iterations and hidden neurons, so random experiments are used to set the iterative parameters and hidden neurons. Two parts of testing the system are recognition of training image and recognition of the testing image. Recognition of training image will use the image saved previously in the database. The result of recognition testing image is the recognition can be recognized 15 of 15 image herb leaves. It proves that the net4 network recognizes the training images perfectly. So, net4 network suitable to test the testing image.

The recognition of testing image will give the percentage of successful recognition of 15 species of herbs leaves. Each type of leaf is taken as 4 images that are not through the training process. The accuration of test results on the testing image for leaves of *beluntas*, *mangkokan*, *katuk*, *soka*, *sirih hijau*, lobelia, and *sirih merah* are 75%. The lowest accuration is for *pecut kuda* leaf about 25%. The highest accuration is for leaves of *dolar*, *keji beling*, *nusa indah*, *sambung darah*, *jeruk purut* and *salam,* that are 100%.

Basically, the Artificial Neural Network works like a human, which is learning a thing from the training process. In this result, not all images can be recognized correctly because the more images used the more chances for the similarity. This causes the recognition leads to the most similar feature, although the feature does not belong to the right object. Based on the results of the testing process and Equation (18), and then obtained the results of the accuration percentage that is equal to 81.6% by using the best network performance.

C. Discussion

The accuration result of recognition using two combinations of feature extraction and classification methods will be compared. The accuration value of each combination can be depicted in the Table 4.

TABLE IV. COMPARISON OF RECOGNITION RATE USING TWO COMBINATION METHODS

No	Methods	Accuration (%)
1	Hu's moment invariants and Backpropagation Neural Network	84.1
2	2D Gabor filter and LVQ	81.6

Table 4 depicts the comparison between two combination methods. As we can see the first combination obtains better recognition rate than the second one. It can't be denied there are several factors that greatly affect the errors in the results of recognition of the image of these herbs.

1. Similarity of leaf shape with one other leaf

In the introduction of these herbs, there are several types of leaves having the shape of leaves are almost similar to each other, such as *Salam* leaf and Soursop leaf that has an oval shape (elliptical), where the middle of the leaves widen.

2. Unsuccessful recognition process

In the scanning process produces an image background with different brightness levels affecting the threshold value when changing RGB image to binary image.

3. Different leaf size

The processes of training data and testing data of these herbs have some variety of leaf sizes that it will complicate the recognition process. It is better to use the same size of an herb leaf, so the shape and characteristics of the leaf do not change.

IV. Conclusion

From the result of two combination methods tested by some testing image, it can be concluded that combination of feature extraction methods and classification methods influence for the accuration of the recognition result. The combination between Hu's moment invariants and Backpropagation Neural Network gives the better result. The highest accuration is 96% and the lowest is 83.7%. The average from all accuration values is 84.1%. The combination of 2D Gabor filter and LVQ has the highest accuration about 100% but the lowest is about 25%. So, the average of accuration percentage is 81.6%. The differences of accuration percentage are influenced by some factors, those are similarity of a leaf shape with another leaf, unsuccessful recognition process, and different size of leaves.

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