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Performance Evaluation of Fuzzy Logic System for *Dendrobium* Identification Based on Leaf Morphology

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Abstract

Dendrobium is the second-largest family of flowering plants in the world. There are several classes of *Dendrobium*, which usually identify by its, including leaves and flowers. Due to the similarity of its characteristics, identifying orchid types is complicated and usually can only be done by an expert. Moreover, those characteristics are typically non-deterministic; examining the orchid species is very challenging. This research aims to develop a novel fuzzy-based system to identify the species of orchid based on unprecise existing leaf characteristics. We used the main characteristics of *Dendrobium* leaves, including shape, length, width, and tips of the leaves. Based on the information from the expert, we develop the membership for each class of *Dendrobium*. By adopting this knowledge, we develop the system by using compatible programming with this case, and Borland Delphi as complex application development. The experiment is done by using 200 real datasets from the Liwa Botanical Gardens, West Lampung Regency, Lampung Province, Indonesia. The results are compared with those given by a *Dendrobium* expert. A confusion matrix is a valuable evaluation tool for measuring the performance of classification models. From the above results, we can determine the confusion matrix and calculate the TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative). The confusion matrix given from the experiments is shown in Table 6. This indicates that the system can provide the same results as experts recommended. It is shown that the system can identify orchid types with an accuracy value of 94,6 %. Thus, this system will be beneficial for automatically determining the orchid genus.

Keywords: Fuzzy Logic, Artificial Intelligence, Orchids, Dendrobium, Leaf Morphology

1. Introduction

Liwa Botanical Garden is a regional botanical garden in Lampung with the theme of ornamental plants. One type of local native orchid in Lampung and a typical flora of southern Sumatera Island which is a mainstay of the collection at the Liwa Botanical Garden is *Dendrobium*. Based on collection data, the largest collection of *Dendrobium* orchids is 48 accession numbers from a total of 805 specimens [1]. The obstacle to the use and conservation of Dendrobium in the Liwa Botanical Garden is identification. This genus consists of 25,000 species in the world, and 900 of them are found in Asia, including in Indonesia. Some members of *Dendrobium* are an endangered orchid species listed in CITES Appendix II. So far, identification is still carried out conventionally based on morphology. The commonly used morphological character is leaf.

The choice of leaf characters is due to the limitations of other organs such as flowers which are the main characteristics of orchid plants. Orchid is plants of the most diverse and extensively dispersed flower groups. They are also one of the few plant families whose characteristics can contribute to large-scale plant conservation. Orchids exhibit a variety of flower shapes, colors, and sizes, each with its own unique characteristics. The distinctive shape and color of the lip or labellum differentiates orchids from other plants. Orchid flowers generally have two different parts, namely sepals (kallix) and petals (corolla), with three each. Our previous morphological identification results [1] on 12 orchid general

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in the Liwa Botanical Gardens, namely *Agrostophyllum*, *Polisthacia*, *Dipodium*, *Eria*, *Trichotosia*, *Pholidota*, *Bulbophyllum*, and *Appendicula*, show similarities in dominant and semi-dominant morphological characters even though they come from the same genus. different, each orchid shows a closer relationship due to the similarity of dominant and semi-dominant morphological characters. The very significant morphological characters between the genera Bulbophyllum and Appendicula generally show more differences than similarities so it could be said that the kinship relationship between the two genera is far apart. Morphological identification of orchids is needed in order to preserve orchid germplasm in Indonesia. Is a process used to determine the phenotypic characteristics of a plant. Morphological identification for a plant can be made by observing the leaves, stems, fruit, flowers, roots, seeds and the entire morphology of the plant body. This statement is the basis for observing the morphology of orchid species in the Liwa Botanical Gardens, which have an important role in systematics and have been widely used to see relationships between plants [2]. Leaf of shape, tip shape, leaf cross-section, leaf arrangement, leaf edge shape, leaf surface texture, leaf symmetry, phyllotaxis are the main criteria in identifying morphology of *Dendrobium* [3].

Based on the previous research, in addition to disease infection other hindrances are also known in conservation and utilization efforts of native *Dendrobium* in Lampung, such as identification. Based on research by Mahfut [1] it is known that leaf morphological characters have limitations so a fast, effective and efficient identification method is needed. Research on *Dendrobium* identification based on leaf morphological characters using a fuzzy logic approach and implemented by the Borland Delpi programming language can provide accuracy in naming *Dendrobium* species. Lestari [4] has conducted a large-scale investigation of orchid images in 103 image classes using 4 features, namely texture, borders, petals and color. On a single feature, the accuracy was 55.1%, while on the combination of all features, the accuracy was 72.8%.

The challenge in calculating accuracy accurately is influenced by the similarity of the large and small classes of each test data input. SVM has also been used in [5] In this study, 13 orchid genotypes were identified using FTIR spectroscopy with 3 models, namely SSAE, SVM, and KNN. SSAE is proven to be more accurate than SVM and KNN. SSAE produces 99.4% accuracy and 97.9% calibration while KNN produces 100% accuracy but only 92.6% calibration. Paphiopedilum orchid species were identified using CNN in research conducted by Nasir [6] using 1500 images and 15 classes with 98.6% accuracy. Image classification was also carried out using Naïve Bayes as a simple statistic and the probability of onion quality achieved high accuracy [7]. Here, Naïve Bayes is combined with a hue saturation value (HSV) color model. Using 60 training and testing data, Naïve Bayes produces 91.67% accuracy. Here, the choice of HSV color model and color channels is adapted to human vision theory which may change with other preprocessing to obtain the highest accuracy [8]. Jayech and Mabjoud compared with tree-augmented Naïve Bayes (TAN) and forest-augmented Naïve Bayes (FAN) [9], regular Naïve Bayes (RN) achieved the highest average classification [10]. A comparative study by Chandel [11] prove that KNN [12] is better than NB with accuracy of 93.44% and 22.56% respectively.

Fuzzy Logic has a value of ambiguity between true and false [13]. A fuzzy matrix is used to represent the position and velocity of particles [14]. Fuzzy Logic is a qualitative computational approach [15], [16]. Fuzzy Logic can be used in control theory, decision theory, and several parts of management science Logic to find relationships and correlations between large data items [17]. The advantage of fuzzy Logic is that it carries out linguistic reasoning. Hence, mathematics equations no longer need to control objects in their design [18]. Fuzzy provides models that humans can easily interpret. This model takes the form of familiar if the implied rules are easy to select with operator (expert) rules [19].

Recently, with the growing popularity of computers, many researchers are introducing technology in the form of artificial intelligence based on expert knowledge to solve several real-life applications, including Interpretation, Prediction, Diagnosis, Design, Planning, Monitoring, and so on [5]. These systems usually transfer expertise and rules from experts. With this system, even lay people can solve quite complex problems that generally can only be solved with the help of experts.

Based on information from experts, we create membership functions for each criterion: shape, length, width, and leaf tip. Then by using this membership function we calculate the membership value. The effectiveness of the system was evaluated using an orchid dataset from the Liwa Botanical Gardens, West Lampung, Lampung Province, Indonesia.

The results provided by the system are compared with the results of orchid experts. Liwa Botanical Gardens is in a sloping and hilly area, with the lowest point 830 meters above sea level and the highest point 945 meters above sea level. Liwa Botanical Gardens has an average annual rainfall of 2500-3000 mm, wet months of 7-9 months, relative humidity of 50-80%, and sun intensity of 37.9%. The topography in the Liwa Botanical Gardens area is sloping and hilly with the lowest point of 830 meters above sea level located in the southern part of the Liwa Botanical Gardens along the Sinda Lapai River and the highest point of 945 meters above sea level located around the receiving zone, with a steep slope class of more than 40%. In order to evaluate the proposed methods, we have done several experiments by using dataset taken form Liwa Botanical Garden [1].

This study will evaluate and analyze the performance of fuzzy based system for cdetermining the type *Dendrobium*. First, based on the information from the expert [20], we develop the membership function for each type of *Dendrobium*. Next, we develop the system. We evaluate the system by using real dataset. Finally, we compare the results with those given by the expert. This paper contains an introduction in Section 1, The proposed method explaining labeling, pre-processing, word weighting, holdout cross-validation, sampling method, and sentiment classification for experiments in Section 2. The results and discussion are in Section 3, conclusions and acknowledgments in Section 4.

2. The Proposed Method

The research workflow starts with data acquisition from Liwa Botanical Garden. After data acquisition, the data undergoes preprocessing. The following step of the procedure and data set. Implementing model fuzzy is the next step. Then created the application. Finally, the last step is evaluating the classification results and diagnosing naming *Dendrobium* using Fuzzy.

This research has several stages of designing a system for determining the species of orchids. The process starts with deciding variables, adopting knowledge, and developing membership. Next is the development of the system stage. Finally, experiments are done to evaluate the functional system and compare the results with those of experts. The process conducted in this study is illustrated in figure 1.

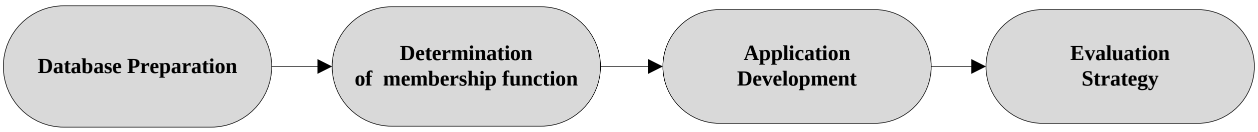

Figure 1. Research Methodology

2.1. Dataset Preparation

First, the data used in this study include ten types of species of *Dendrobium* where we identified 10 species types of dendrobiums which will be used as a dataset, where each *Dendrobium* has different characteristics, including leaf shape, length, width and leaf tip., as presented in Table 1.

Table 1. *Dendrobium* Species Data

Code	Types
D01	*D. cetifolium*
D02	*D. anae*
D03	*D. crumenatum,*
D04	*D. montanum*
D05	*D. babience*
D06	*D. nobile*
D07	*D. phalaenopsis*
D08	*D. taurium*
D09	*D. cucumerium*
D10	*D. spectacular*

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2.2. Determination of Membership Function

The membership function is a curve that shows the mapping of input data points into their membership values or degrees, which have an interval between 0 and 1 [16], [17]. The membership function is a set of real numbers whose range is positive numbers in the closed interval [13]. One way that can be used to obtain membership values from fuzzy sets is through the membership function approach [21]. The curve used is the Triangle Curve (see figure 2). This curve is basically a combination of 2 lines (linear). This model curve is appropriate to use because of the suitability of the knowledge base for finding the middle value.

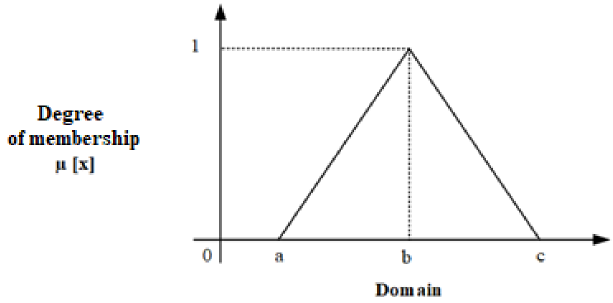


Figure 2. Membership curve of pelvises representation

$$\mu[x]=\begin{cases} 0 & x\leq a \text{ or } x\geq c \\ (a-b)/(b-a) & a\leq x \leq b \\ (b-x)/(c-b) & b\leq x\leq c \end{cases} \tag{1}$$

In fuzzy set theory, with this equation (1) its make the role of membership value as a determinant of the existence of elements in a set is vital [21]. Membership value is the main characteristic of reasoning with fuzzy Logic [13]. The use of fuzzy relations stems from real-life observations that can be related to each other to a certain degree (such elements can be part of a fuzzy set to a certain degree); in this case, they can model fuzziness. However, they are still intolerant of uncertainty because there are no mean values to attribute information reliability or confidence to the degree of membership [22].

2.3. Application Development

In order to evaluate the effectiveness of the system, the researchers conducted intensive experiments based on hundreds of *Dendrobium* data taken from Liwa Botanical Garden. We developed an application using Pascal programming with the Delphi GUI and run on PC Processor Intel® Core™ i3-7020U.

2.4. Evaluation Strategy

A confusion matrix is a valuable evaluation tool for measuring the performance of classification models. From the above results, we can determine the confusion matrix and calculate shown in table 5. The confusion matrix given from the experiments is shown in table 6. This indicates that the system can provide the same results as experts recommended. The overall performance measurements of the system are given in table 7.

3. Experimental Design and Result

3.1. Dataset Preparation

This dataset provides functions for collecting, organizing, and retrieving computerised knowledge [13]. This database knowledge is designed based on the expert knowledge of Dr. Mahfut from the University of Lampung. The species of *Dendrobium* are determined by leaf shape, length, width, and leaf tip. Those are summarized in table 2.

Table 2. *Dendrobium* Species by Leaf Morphology Based on Experts

Type	Leaf Shape	Length (cm)	Width (cm)	Leaf Tip
D. cetifolium	Ovatus	10.6	7.5	Acuminate
D. anae	Pelvatus	12.7	10.2	Acuminate

D. crumenatum	Ovatus	5.0	6.5	Obtuse
D. montanum	Ovatus	15.2	10.5	Acuminate
D. babience	Ovatus	14.0	9.0	Acuminate
D. nobility	Cordatus	19.5	12.6	Acute
D. phalaenopsis	Cordatus	15.6	6.8	Acuminate
D. taurium	Ovatus	18.0	7.6	Acuminate
D. cucumber	Ovatus	12.5	18.0	Acuminate
D. spectacular	Ovatus	9.2	11.1	Acute

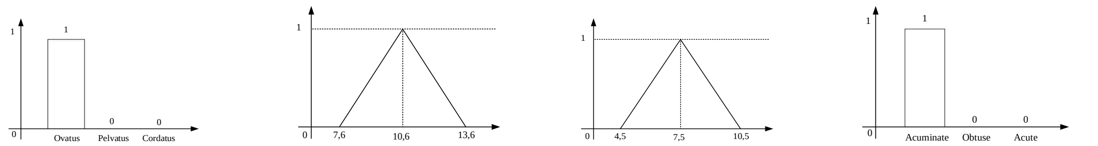
3.2. Determination of Membership Function

In this research, based on the information from the expert, we developed the membership function of each species, as given in table 3.

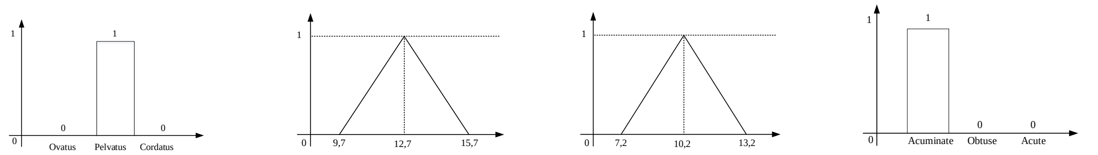
Table 3. Membership function for each type of *Dendrobium*

Variable	Leaf shape	Length (cm)	Width (cm)	Leaf Tip

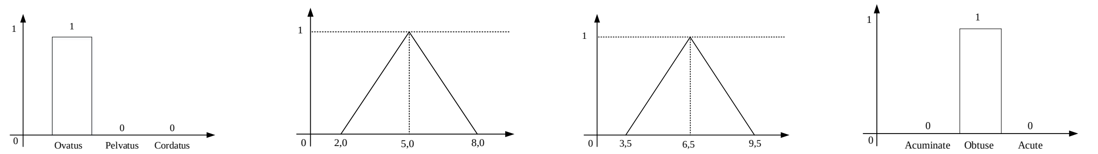
D. cetifolium



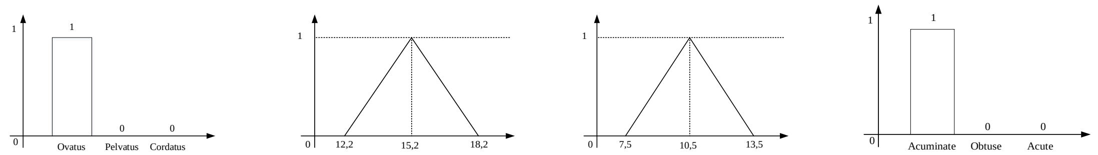
D. anae



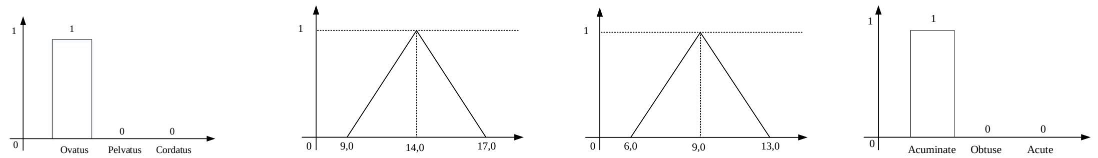
D. crumenatum



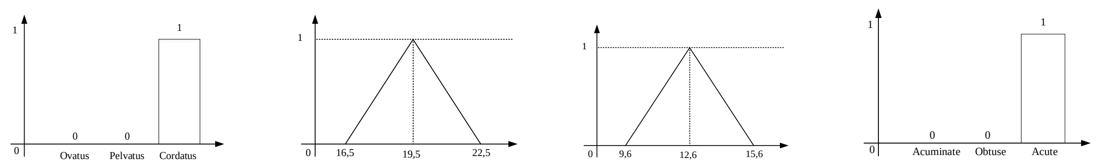
D. montanum



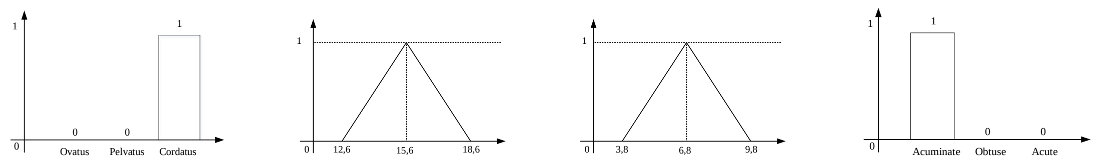
D. babience

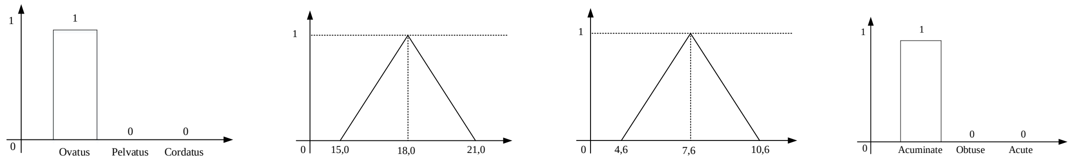
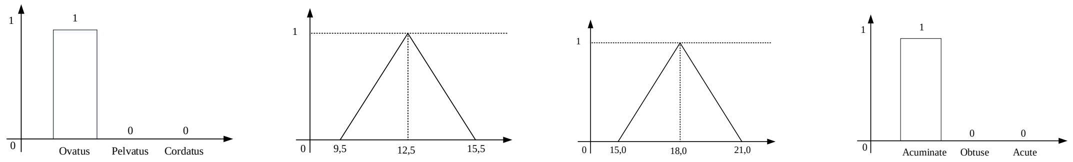
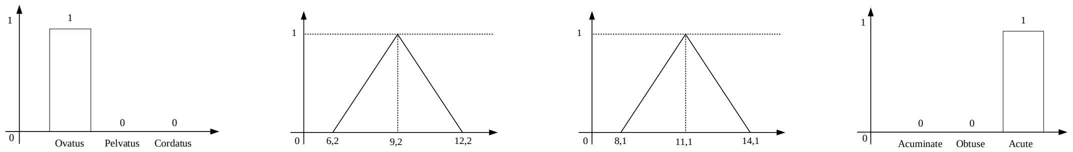


D. nobile



D. phalaenopsis



D. taurium	
D. cucumber	
D. spectacular	

3.3. Application Development

This system first displays the user interface, as shown in figure 3. The users could fill in the criteria data and press the process button to display the calculation results. After entering the parameters, the system will present the results. We used 200 (two hundred) test problems, images taken from Liwa Botanical Garden, for the experiments. Then, we compared the system results with those provided by the expert. The overall results are summarized in table 4.

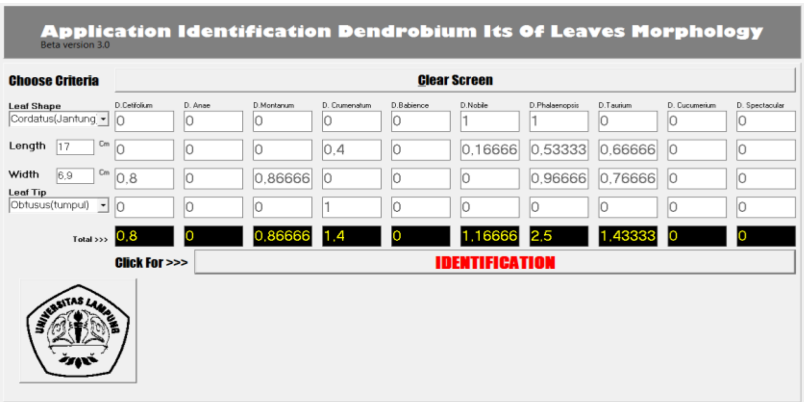


Figure 3. *Dendrobium* identification page based on leaf morphology

Evaluation is carried out to calculate the proposed system's accuracy and the experts' recommendations. Table 4 displays the *Dendrobium* identification results from the Systems and experts.

Table 4. Comparative Results Between Expert and System

No	Leaf Shape	Length	Width	Leaf Tip	Experts	System	Information
1	Ovatus	17.3	10.0	Acuminate	*D. tourium*	*D. taurium*	In accordance
2	Pelvatus	11.0	20.0	Acuminate	*D. anae*	*D. anae*	In accordance
3	Cordatus	9.5	9.4	Acute	*D. spectacular*	*D. spectacular*	In accordance
4	Cordatus	13.0	11.0	Acuminate	*D. anae*	*D. anae*	In accordance
5	Ovatus	12.0	7.6	Obtuse	*D. cetifolium*	*D. phalaenopsis*	Is'nt accordance
6	Pelvatus	10.6	9.0	Acuminate	*D. anae*	*D. anae*	In accordance
7	Ovatus	15.0	8.0	Obtuse	*D. montanum*	*Montanum*	In accordance
8	Ovatus	16.3	12.4	Acuminate	*D. nobile*	*D. nobile*	In accordance
9	Cordatus	17.0	6.9	Obtuse	*D. phalaenopsis*	*D. phalaenopsis*	In accordance
10	Pelvatus	12.4	7.2	Acute	*D. anae*	*D. phalaenopsis*	Is'nt accordance
11	Ovatus	10.0	9.0	Acuminate	*D. cetifolium*	*D. cetifolium*	In accordance

12	Pelvatus	9.6	13.0	Acuminate	*D. anae*	*D. anae*	In accordance
13	Ovatus	18.0	14.0	Obtuse	*D. montanum*	*D. montanum*	In accordance
14	Cordatus	14.0	10.8	Acute	*D. spectacular*	*D. spectacular*	In accordance
15	Pelvatus	13.7	12.0	Acute	*D. anae*	*D. anae*	In accordance
16	Cordatus	5.0	6.8	Acuminate	*D. phalaenopsis*	*D. phalaenopsis*	In accordance
17	Ovatus	5.0	6.5	Acute	*D. Crumenatum*	*D. Crumenatum*	In accordance
18	Ovatus	8.2	10.5	Acuminate	*D. spectacular*	*Spectacular*	In accordance
19	Cordatus	9.0	11.1	Obtuse	*D. spectacular*	*Spectacular*	In accordance
20	Ovatus	15.0	18.0	Acuminate	*D. cucumber*	*D. cucumber*	In accordance

3.4. Evaluation Strategy

This section explains several things. By obtaining similar morphological data in the field for all samples with the system created, it shows that the expert dataset collected can be identified accurately using the system, so that there are no gaps or differences in assessments. These results suggest that the accuracy of the 200 test case data is 94.6 % correct. Thus, we can be sure that this system is effective. Based on table 7, it presents findings from a comparison of 20 data points between experts and systems, which shows that there is a match between the two. Table 5 then displays data from the confusion matrix between predictions made by the system and actual expert data. Based on these results, it shows that of the 10 orchids. The performance measurement of the ten Dendrobium orchids is presented in table 6 with a percentage accuracy level of 96.4 % with performance results including accuracy, precision, recall, specify, and F1-Score.

Table 5. Application testing confusion matrix

TP	TN	FP	FN
6	83	0	11
6	90	0	4
2	94	0	4
7	85	0	8
5	92	0	3
2	96	0	2
3	90	0	7
1	94	0	5
21	73	0	6
50	46	0	4

Table 6. Confusion matrix results

		Predicted by the System									
	Type of Character	**D01**	**D02**	**D03**	**D04**	**D05**	**D06**	**D07**	**D08**	**D09**	**D10**
Actual by the expert	D01	6	0	0	0	0	0	0	0	0	0
	D02	0	6	0	0	0	0	0	0	0	0
	D03	0	0	2	0	0	0	0	0	0	0
	D04	0	0	0	7	0	0	0	0	0	0
	D05	0	0	0	0	5	0	0	0	0	0
	D06	0	0	0	0	0	2	0	0	0	0
	D07	0	0	0	0	0	0	3	0	0	0
	D08	0	0	0	0	0	0	0	1	0	0
	D09	0	0	0	0	0	0	0	0	21	0
	D10	0	0	0	0	0	0	0	0	0	50

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Table 7. Performance measurement results

***Dendrobium* Species**	**Accuracy**	**Precision**	**Recall**	**Specificity**	**F1-Score**
D.cetifolium	0.89	1.00	0.35	1.00	0.52
D.anae	0.96	1.00	0.60	1.00	0.75
D.crumenantum	0.96	1.00	0.33	1.00	0.50
D.montanum	0.92	1.00	0.47	1.00	0.64
D.babience	0.97	1.00	0.63	1.00	0.77
D.nobile	0.98	1.00	0.50	1.00	0.67
D.phaleonopsis	0.93	1.00	0.30	1.00	0.46
D.taurium	0.95	1.00	0.17	1.00	0.29
D.cucumber	0.94	1.00	0.78	1.00	0.88
D.spectacular	0.96	1.00	0.93	1.00	0.96

4. Conclusion

This research develops a new fuzzy logic system to identify the Dendrobium genus. This system aims to determine the genus based on leaf morphology, including leaf shape, length, width and leaf tip. The system calculates the membership model for each criterion and determines the membership value for each orchid species. After determining the value, it will be plotted in a curve and will be implemented into a Borland Delphi based application. The system has been tested using 200 real datasets collected by experts from gardens from the Liwa Botanical Gardens, West Lampung, Lampung Province, Indonesia. The results are compared with those given by experts. This shows that the system can identify orchid species accurately in all tests. Thus, this system is very useful for supporting researchers and in the future it can be used as a research support medium

5. Declarations

5.1. Author Contributions

Conceptualization: A.S.P., A.S., M., S.R.S., M.S.H.; Methodology: A.S., M.; Software: A.S.P.; Validation: A.S.P., A.S., M.; Formal Analysis: A.S.P., A.S., M.; Investigation: A.S.P.; Resources: A.S.; Data Curation: A.S.; Writing Original Draft Preparation: A.S.P., A.S., M., S.R.S., M.S.H.; Writing Review and Editing: A.S., M., A.S.P.; Visualization: A.S.P.; All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

5.4. Institutional Review Board Statement

Not applicable.

5.5. Informed Consent Statement

Not applicable.

5.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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