Accuracy of Fuzzy Logic Based Contamination Grading System on Abaca Tissue Culture

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***Abstract*—**This study aims to support the coalition for abaca rehabilitation program of Southern Leyte State University (SLSU) and the different cooperating agencies of Southern Leyte. This is with use of intelligent systems in the grading of abaca tissue culture contamination. Since the abaca tissue culture laboratory is doing manual grading of the contaminated specimen, the use of image acquisition technology such can lessen the human interaction. Fuzzy logic is being used in the grading of the contamination. There are five (5) inputs for the inference engine namely red, green, blue, whitish and brownish. There are 62 rules identified covering the different combinations and the triangular-shaped membership function is used for all the membership types of the inputs. Based on the result of the testing, it has an accuracy rate of 82.00% for the binary contamination in 50 sample specimens and over-all accuracy of 80.33% in multiclass contamination grading. The system could not match the precision of the human expert, but the model is comparable to that of the expected actual result while minimizing the human intervention in the grading the contamination of abaca tissue culture.

***Keywords*—** algorithm, automated grading, decision-making.

I. Introduction

The Philippines supplied 84% of the global production of abaca- which is equivalent to an average fiber production of 68,982 t yr-1 - from 1999 to 2008. The Eastern Visayas region (islands of Leyte, Biliran, Samar and Pana-on) was the major abaca producer that supplied the bulk of the product contributing an annual average of 25,517 tons or 38.5% of the total production [1]. The average annual yield in Eastern Visayas is 913 kg fiber ha-1, which is above the national annual average of 610 kg ha-1 [2] but far behind the potential yield of 2,000 kg of fiber ha-1 [3].

The fiber of abaca is used as a raw material for pulp and paper, fiber craft, cordage [4] and even garment accessories. Moreover, for farmers who rely on abaca as source of their income, it is a must to plant healthy abaca specimen for a better harvest also.

However, challenges are inevitable. Plant diseases in agriculture are a normal phenomenon. In the case of the province of Southern Leyte in 2003, where eighty per cent (80%) of the province's abaca plantation was widely affected and was estimated to suffer about thirty per cent (30%) in damages because of abaca disease [5]. With the help of technology, earlier detection of the diseases might have prevented or at least minimized the effects brought upon by the infection.

Trends of research in agriculture aim towards the development of the disease resistant variant of seed using gene technology, which increase productivity and food quality at reduced expenditure [6]. Plant tissue culture technology is widely utilized for a large scale plant multiplication. Even though it is possible to produce a large number of plants by micro propagation, the greatest problem in this technique is contamination [7]. Tissue culture can become contaminated at any stage. Hence, this study is conducted to grade the severity of contaminants for tissue culture using fuzzy logic.

II. Related Studies

The manual and naked eye observation of experts is the main approach adopted in practice for detection and identification of plant diseases [8]. It is the observation method generally used to decide the diseases severity in the production practice but results are subjective and it is not possible to measure the disease extent precisely [9]. Manual visual inspection is also done to tissue cultures of abaca inside the Abaca Research Center of Southern Leyte State University, Sogod, Southern Leyte.

In the study of Fakhri, et al. in the application of image processing in agriculture, the researchers mentioned that the use of information and communications technology (ICT) in agriculture is increasing day by day. IT equipment and software has become cheaper with technological advancement [10]. In the study of A.H. Kulkarni, et.al. [11], the authors proposed a novel framework for recognizing and identifying plants using shape, vein, color, texture features which are combined with Zernike movements.

The paper of Sanakki S.S. et al. also proposes an image processing methodology to address one of the core issues of plant pathology i.e. disease identification and its grading. Their system is an efficient module that identifies various diseases of pomegranate plant and also determines the stage in which the disease is by grading them [12].

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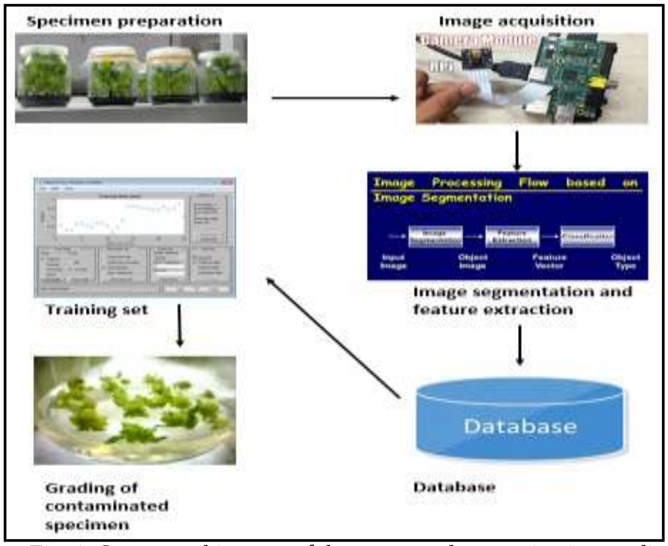

Fig. 1: System architecture of the automated contamination grading of the abaca tissue culture

Fuzzy logic, one of the decision-making techniques of artificial intelligence, has been proven to be applicable in almost all scientific fields. The aim of application of fuzzy logic in image processing is based on identification of objects or achievement of healthy perception and more realistic results in image clarity [13].

In a study of Apple Grading Using Fuzzy Logic (FL), the author applied FL as a decision making support to grade apples. The same set of apples was graded by both a human expert and a FL system designed. The study obtained results in agreement with the results from the human expert. The outcome of the study also provided good flexibility in reflecting the expert's expectations and grading standards. The author suggested to fully automate the system by using machine vision in the decision making using fuzzy logic [14].

III. Methodology and Procedure

A. Specimen Preparation

The laboratory technician prepares the specimen in the laboratory room.

B. Image Acquisition

With the use of a 12 megapixel camera, raspberry pi microcontroller, OpenV, and Xbee wireless data transmission; images of both healthy and contaminated specimens are captured.

C. Image Segmentation and Feature Extraction

The region of interest (ROI), which is the plant image, is separated from the background. Images are converted from video streams into binary thus indicating the segmentation of the specimens. After segmentation, color, morphological and texture features were extracted. Masking is applied onto the image to obtain useful segment. The red, green and blue component of the pixel is assigned to a value of zero by mapping of RGB components. These values are stored in the database to be used for the next step.

D. Fuzzy Logic Classification

Lotfi Zadeh, a professor at the University of California at Berkeley, conceived and introduced the concept of Fuzzy Logic (FL). It is described as a problem-solving control system methodology that lends itself to implementation of different systems, which can be implemented in hardware, software, or a combination of both. FL's approach to control problem imitates how a person would make decisions, only much faster.

Fuzzy Logic requires Fuzzy Rules and Inference to transform fuzzy input sets to crisp outputs. The transformation process incorporates a simple, rule-based IF X AND Y THEN Z approach to a solving control problem rather than attempting to model a system mathematically

Fuzzy logic deals with propositions that can be true to a certain degree—somewhere from 0 to 1. Therefore, a proposition's truth value indicates the degree of certainty about which the proposition is true [15]. It is suitable to handle ill-defined and complex problems due to the partial and imprecise information for decision making. The process of fuzzy logic can be defined as rule-based systems, in which the input is first fuzzified (i.e., converted from a crisp number to a fuzzy set) and subsequently processed by an inference engine.

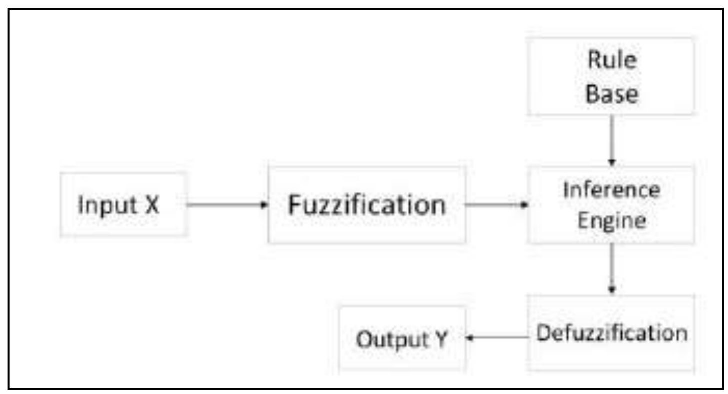

Fig. 2: Fuzzy rule-based scheme

This engine retrieves the knowledge in the form of fuzzy rules contained in a rule-base.

The fuzzy sets computed by the fuzzy inference as the output of each rule are then composed and defuzzified (i.e., converted from a fuzzy set to a crisp number) [16]. Fig. 2 shows the Fuzzy rule-based system scheme and Table 1 shows an example of Fuzzy rules used to diagnosis Discus fish disease [17].

E. Training and Testing

The specimens are prepared in the Abaca tissue culture laboratory by the technician. Averages of 500 specimens are prepared daily. Plant tissue culture technology is being widely used for a large scale plant multiplication. Even though it is possible to produce a large number of plants by micro propagation, the greatest problem in this technique is contamination. A wide range of microorganisms (filamentous fungi, yeast, bacteria, viruses and viroids) and micro-arthropods (mites and thrips) have been identified as

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contaminants in plant tissue cultures [4].

In this phase, the decision of the laboratory technician was evaluated in actual contamination grading. Table 1 shows the principal microbial contaminants frequently reported in vitro cultures.

TABLE I:
CHARACTERIZATION AND IDENTIFICATION OF FUNGAL CONTAMINANTS OF TISSUE-CULTURES ABACA (MUSA TEXTILES NEE) [18]

Contaminants	Cultural Characteristics	Morphological Characteristics
Aspergillus sp.	Colonies are flat, circle, filamentous, velvety, woolly or cottony texture. Colony color is gray to green at center with a white border. The reverse is yellow to pale yellow	Conidiophores bears heads, long and hyaline that terminates in bulbous heads while conidia are globose to subglobose and usually yellowish green and dark brown
Chrysosporium sp.	Colonies are semi-elevated, circle, fairly rapid grower, smooth. Colony color is white to off white color.	Produced septate, hyaline hypae. Conidia often appeared to be minimally differentiated from the hypae and may appear to form directly on the hyphae. Conidia more often formed at the ends of simple or branched conidiophores of varying lengths. Conidiophores were ramifies, forming tree-like structure.

The execution of simulation was done using the MATLAB Simulink tool box. The goal was to design a Fuzzy logic based grading of abaca tissue culture contamination. . Fig. 3 shows the Fuzzy Inference System (FIS) model for the contamination grading of the abaca tissue culture.

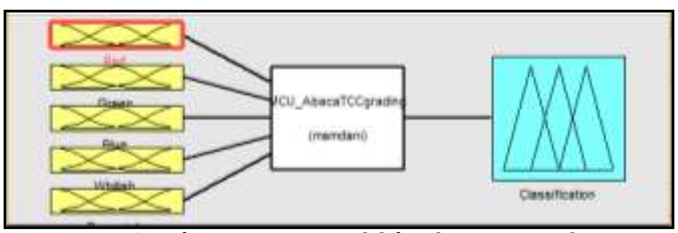

Fig. 3: Inference system model for abaca tissue culture contamination grading.

The inputs of the infrence system are Red, Green, Blue, Whitish, and Brownish. Linguisetic values for all the inputs are Level 1, Level 2, Level 3, Level 4, Level 5, Level 6, and Level 7. Table 3 shows the linguistic values, MF types and universe of discourse of the Red input. The values on the universe of discourse are the binary values of the color red during the image processing. Figures 4,5,6,7 and 8 show the membership function of the input variables.

TABLE II: LINGUISTIC VALUES, MEMBERSHIP FUNCTION TYPES AND UNIVERSE OF DISCOURSE FOR THE FUZZY LOGIC INPUT RED.

Input	Linguistic Values	MF Type	Universe of Discourse
Red	Level 1	trimf	[6.0 6.711 7.5]
	Level 2	trimf	[7.08 7.87 8.81]
	Level 3	trimf	[8.01 9.092 10]
	Level 4	trimf	[9.4 10.4 11.2]
	Level 5	trimf	[10.6 11.61 12.5]
	Level 6	trimf	[11.6 12.71 13.6]
	Level 7	trimf	[12.74 13.5 14]

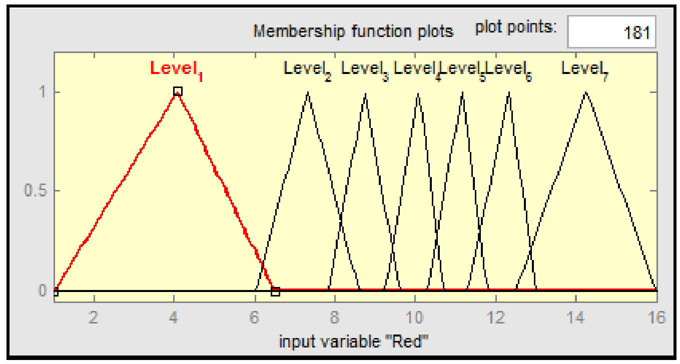

Fig. 4: Membership function of the input variable Red

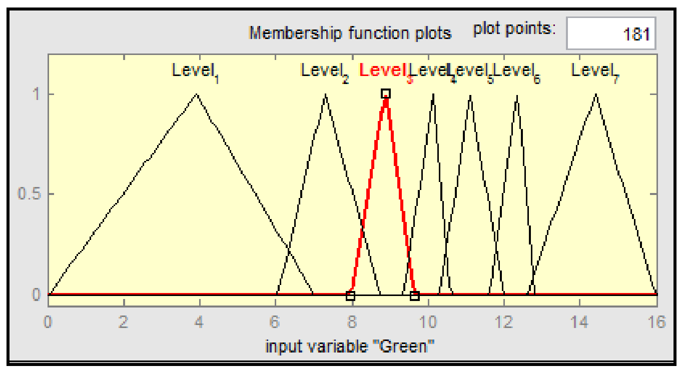

Fig. 5: Membership function of the input variable Green

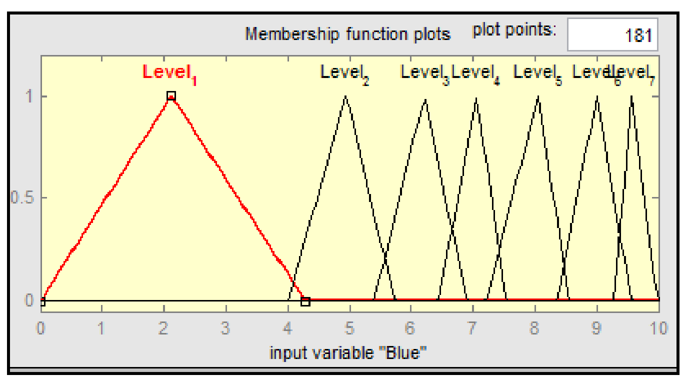

Fig. 6: Membership function of the input variable Blue

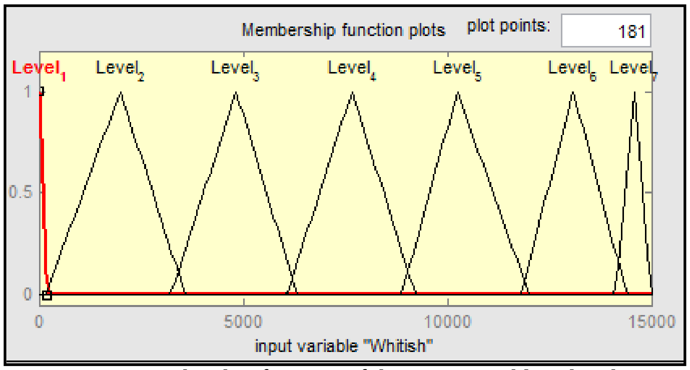

Fig. 7: Membership function of the input variable Whitish

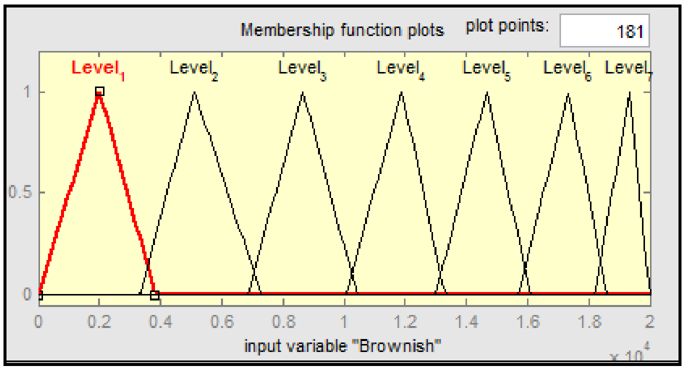

Fig. 8: Membership function of the input variable Brownish

A total of 62 rules were identified for the grading of the specimens as healthy, moderately contaminated and heavily contaminated. Fig. 9 shows the membership function of the variable output Classification.

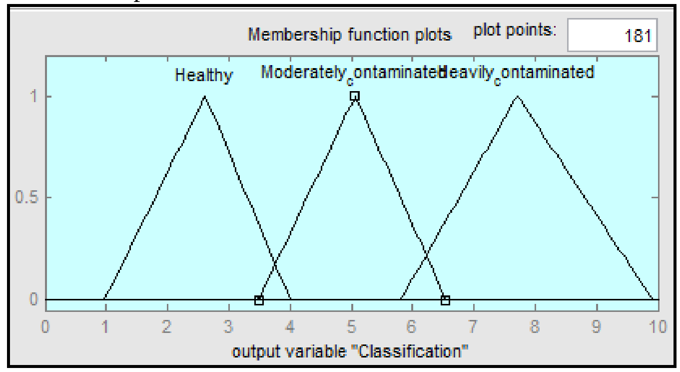

Fig. 9: Membership function for the output variable Classification

IV. Results and Discussion

The system was trained using 200 samples of abaca tissue culture [18]. Different values of the training parameters were obtained. The training parameters are Red, Green, Blue, White and Brown. These parameters are being used as inputs to the Fuzzy Inference System. Fig. 10 is the top ten rules being followed in the FIS.

1. If (Red is Level_6) and (Green is Level_6) and (Blue is Level_6) and (Whitish is Level_5) and (Brownish is Level_2) then (Classification is Healthy) (1)
2. If (Red is Level_6) and (Green is Level_6) and (Blue is Level_6) and (Whitish is Level_4) and (Brownish is Level_5) then (Classification is Healthy) (1)
3. If (Red is Level_7) and (Green is Level_6) and (Blue is Level_6) and (Whitish is Level_4) and (Brownish is Level_5) then (Classification is Healthy) (1)
4. If (Red is Level_6) and (Green is Level_5) and (Blue is Level_5) and (Whitish is Level_1) and (Brownish is Level_6) then (Classification is Healthy) (1)
5. If (Red is Level_6) and (Green is Level_6) and (Blue is Level_5) and (Whitish is Level_2) and (Brownish is Level_7) then (Classification is Healthy) (1)
6. If (Red is Level_5) and (Green is Level_5) and (Blue is Level_5) and (Whitish is Level_2) and (Brownish is Level_5) then (Classification is Healthy) (1)
7. If (Red is Level_7) and (Green is Level_7) and (Blue is Level_7) and (Whitish is Level_4) and (Brownish is Level_6) then (Classification is Healthy) (1)
8. If (Red is Level_7) and (Green is Level_7) and (Blue is Level_7) and (Whitish is Level_4) and (Brownish is Level_5) then (Classification is Healthy) (1)
9. If (Red is Level_4) and (Green is Level_4) and (Blue is Level_4) and (Whitish is Level_2) and (Brownish is Level_4) then (Classification is Healthy) (1)

Fig. 10: Top 10 rules of the Fuzzy Inference System

Table 3 shows the data for the testing. Fifty (50) specimens tested were composed of 15 healthy specimens or contamination free and thirty-five (35) specimens for contaminated.

TABLE III:
BINARY CONTAMINATION GRADING

	Identified by lab technician	**Identified by FIS**	**Accuracy**
Healthy	15	11	73.33%
Contaminated	35	30	81.71%
		Total accuracy	82.00%

The accuracy is computed using the formula shown in equation 1.

$$accuracy = \frac{True\ Positive}{Total\ Samples} \times 100 \quad (1)$$

Where True Positive = number of samples whose variety is correctly identified.

It has also been noticed during that testing that the results of the grading contamination for fuzzy logic is comparable to the result of the testing using KNN where K=7 based on another study [18].

Table 4 shows the data for testing. One hundred (100) specimens tested were composed of 40 healthy specimens, 40 moderately contaminated, and 20 heavily contaminated specimens.

TABLE IV: MULTICLASS CONTAMINATION GRADING

	Identified by lab technician	**Identified by FIS**	**Accuracy**
Healthy	40	35	87.5%
Moderately	40	30	75%
Heavily	20	16	80%
		Total accuracy	80.33%

Fig. 11 shows a moderately contaminated and heavily contaminated specimen of abaca tissue culture used during the testing.

a.) healthy b.) moderate c.) critical d.) critical

Fig. 11: The different samples of contamination specimens

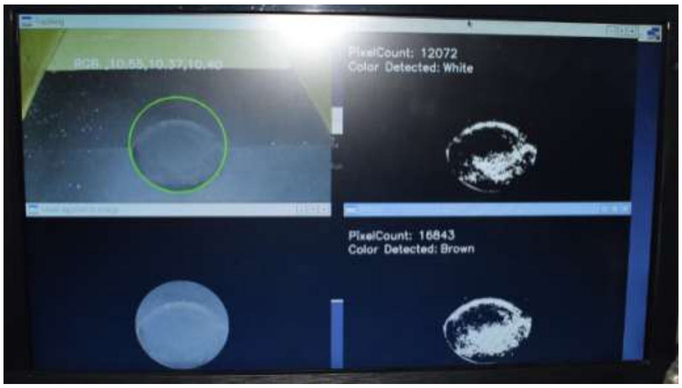

Fig. 12: The monitor showing the feature extraction during the training phase

Fig. 13: Preparation of abaca tissue culture specimen (in vitro)

V. Conclusion

The study of another theorist has an average overall accuracy of 76% for Naïve Bayesian classification while for K=3 were 68% and for K=7 were 58% for K-Nearest Neighbours. The performance was based on accuracy, precision and recall [18]. The contamination grading of abaca tissue culture using fuzzy logic is also able to accurately grade the contamination classification based on the simulation and counterchecked by the human expert. There 62 rules identified covering possible combinations of the different levels of the parameters.

The parameters of the universe of discourse are the binary values of the five (5) input variables namely Red, Blue, Green, White, and Brown extracted during the image processing. The triangular-shaped membership function (trimf) was used for all the linguistic value of the inputs. Based on the simulations conducted using the tested values of the same study [18], and although the system could not match the precision of the human expert, the accuracy result of 82.00% in binary contamination grading and 80.33% in multiclass contamination grading of the model is comparable to that of the expected actual result while minimizing the human intervention in the grading of the abaca tissue culture contamination.

VI. Future Work

The model of this study was limited only to testing in a controlled environment. It would be a good area of research to continue the testing on the open field of an abaca plantation to do automated grading of the diseases of abaca to help prevent / minimize contamination.

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