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Analysing the Quality of Phaseolus Vulgaris Family of Legumes using Artificial Neural Network and "Bag of Features" Techniques

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Abstract*: The Philippine Council for Agriculture, Forestry and National Resources Research and Development-Department of Science and Technology (PCAARRD-DOST) have recognized the importance of cultivating legumes as priority crop among others in the vegetable industry under the National Vegetable Research & Development Program. They have further emphasized the need for innovating the methods to improve the processes in terms of producing better quality of products. The study developed a prototype compiled application based on the trained and validated dataset using ANN (Artificial Neural Network) machine. The BoF (Bag of Features) technique was utilized for image features extraction in the SVM (Support Vector Machine) environment for quality classification of Phaseolus Vulgaris family of legumes. These are commonly cultivated in the Philippines. The combined methods yielded an accuracy of 90.2%.

***Index Terms*: ANN, Bag of Features, compiled application, digital image processing, SVM**

I. INTRODUCTION

Snap beans and long beans are from the family of Phaseolus vulgaris of Leguminosae, the pods contain a good source of proteins, vitamin A, thiamin, riboflavin, iron, phosphorus and potassium [1]. Thus, the Philippine Council for Agriculture, Forestry and National Resources Research and Development Department of Science and Technology (PCAARRD-DOST) has recognized the importance of cultivating legumes to the industry, identified snap beans and long beans, among others, as priority crops under the National Vegetable Research and Development Program [2].

Application of technology in a computer-aided is also one of the main goals of this paper in order to accomplish its set objectives. The study deals with image processing using "bag of features" BoF technique in image extraction for features descriptor for classification that determines the quality of legumes of type Phaseolus Vulgaris. Included in digital image processing are capturing of images, the pre-processing phase of images and image analysis of results and classification of images of interest [3]. The motivational factors of this undertaking are to create a prototype compiled binary application using ANN and BoF techniques in effectively analyzing the quality of vegetables such as Snap and Long beans varieties that will greatly help the cultivators in determining the quality of crops they will be harvesting and to help the vegetable vendors to easily sort and classify what grade of vegetables they will be selling to the direct consumers.

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II. RELATED WORKS

Freshness is the main reason for the consumers in buying vegetables and this preference can be attributed by vegetable's color while others are their appearance as an indication of freshness and flavor quality. Consumers have a preferred color for a specific item like vegetables should not be brown and colors that are not appropriate for the item, indicative of loss of freshness or suggestive of lack of ripeness [4]. These findings on color preferences are adopted in the concept of quality classification of Snap beans and Long beans as the subjects of the study. Image processing through computer technology defines as the process of applying methods to run machines in an automatic inspection using an imaging-based, process control and robot monitoring systems in industrial applications [5]. Computer-aided technology was used to acquire and analyze images of actual scenes to process machines. This method captures processes and analyses images to enable the objectives and non-destructive evaluation of chromatic quality appearances in agricultural and food products [6]. The potentials of Artificial Neural Network (ANN) was presented by Bhole & Patil [7], that was able to determine the classification of different vegetables through their leaves using MATLAB coding for vegetable recognition and had recognized some limitation on the program with regards to the accuracy in classifying leaves with defects. This study has adopted the same concept to produce good data set using some of the techniques presented in the study in incorporation with the "bag of features" (BoF) method for classification of the subject under study.

A. Image Processing

Image processing in agricultural applications consist of three steps: (1) image enhancement, (2) image feature extraction and (3) image feature classification. Noise is one of the problems in digital imaging and to correct this problem image enhancement must be processed procedures such as morphological operations and filters. Pixilation also is commonly applied to check irregularities in the captured photos affected by insufficient and/or non-uniform lighting [5].

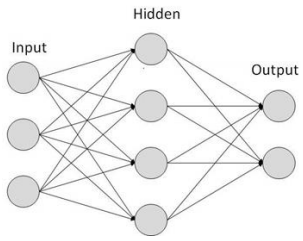

Fig.1An Artificial Neural Network (ANN) structure.

Figure 1 depicts an ANN structure that resembles the neurons' brain that represents a computational model where layers are connected by nodes. A neural network is learning trained- data for pattern recognition, data classification and forecasting of supervised and unsupervised learning [8].

B. "Bag of Features" (BoF) Classifier

Over the past decades, the Bag of Features (BoF) method for computer-aided has become a well-recognized paradigm in image processing for image classification. BoF is a bundle of an unordered collection of image features.

The BoF derives its principle on its predecessor "Bag of Words" (BoW) for using texts representation model for document classification. The texts in BoF represent the "features" of the images as an unordered collection of visual words that can be visualized by a predominantly compressed description of images as histograms of local descriptors to create a vocabulary of visual words by quantizing the local descriptors (features) in the dataset [9].

Thai, et.al [10], utilized the collaboration between the ANN and SVM (Support Vector Machine) methods for Roman numerals recognition application. This SVM was used to combine all of ANN's weighted values as classified outputs. The study had acquired 86% for the precision rate.

Kuźniar, et.al [11], presented the different types of pre-processing that include the use of Back Propagation Neural Networks (BPNNs) for the computation of the natural frequencies of the modified structures necessary in building the design in seismic areas. The study-proven the accuracy of neural networks with various input data pre-processing routines was estimated by mean square error (MSE) and relative errors (ep):

$$MSE = \frac{1}{Q}\sum_{p=1}^{Q}(z^{(p)} - y^{(p)})^2, \quad (1)$$

$$ep = |1 - y^{(p)}/z^{(p)}| \cdot 100\%, \quad (2)$$

$$ep\max = \max_p ep, \quad (3)$$

$$ep\text{average} = \frac{1}{Q}\sum_{p=1}^{Q} ep, \quad (4)$$

Where z(p), y(p)– target and neutrally computed outputs for the p-h pattern, and Q=L, V, T – a number of the learning (L), validating (V) and testing (T) patterns, respectively. The numerical efficiency of the networks was also evaluated by the coefficient of linear correlation for the testing (rT) and the success ratio (SR). The SR function enabled to estimate what percentage of patterns SR (%) gives the neural prediction with the error not greater than ep (%). The paper's result stated that there is a significant influence using neural network input data scaling on the accuracy of the neural prediction in natural frequencies for wall modification on structural designs.

B.1. SURF

Speeded Up Robust Features (SURF) is an algorithm used as feature descriptors in image classification for extraction of key points in finding similarity between images by dividing an image into sub-regions that make the method faster and less noise-sensitive. SURF is based on the Hessian matrix and relies on its determinant to select the best response across a range of scales. Hence, it integrates the scale-space theory introduced by Lindeberg.

$$H(x, \sigma) = \begin{bmatrix} L_{xx}(x, \sigma) & L_{xy}(x, \sigma) \\ L_{yy}(x, \sigma) & L_{xy}(x, \sigma) \end{bmatrix} \quad (5)$$

where $L_{xx}(x, \sigma)$ is the second-order partial derivative $\partial 2 \partial$ x $2g(\alpha)$ with the image I at point x and can be estimated by the convolution of I with a second-order derivative of a Gaussian kernel (LoG); $L_{yy}(x, \sigma)$and $L_{xy}(x,\sigma)$ can be estimated similarly. SURF also estimates the second-order Gaussian derivatives using box filters based on integral images [12].

III. THE PROPOSED FRAMEWORK

This paper presents a model on combining different techniques in answering the proposed objectives. It has utilized the ANN method invalidating a good data set to be fed in SVM paradigm in classifying the quality of Long beans and Snap beans of Phaseolus Vulgaris family of legumes.

A. The Combination Framework

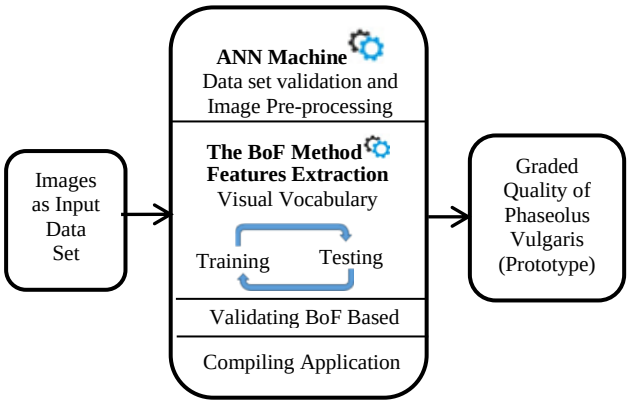

Fig.2. Framework for combining ANN and BoF methods for Long beans and Snap beans from the family of legumes in quality classification.

The proposed framework that started in image acquisition of legumes for Phaseolus Vulgaris family particularly snaps beans and long beans varieties, using an Android mobile camera. Captured images will then be loaded in a machine computing software for pre-processing for acquiring validated data set using the ANN method.

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In the next step, features of the samples are to be extracted such as color, shape, and size from the samples to create the textrons visual vocabulary of BoF. Next step is for learning and training the data set to a BoF machine, and then the subject sample is selected for testing and validating the outputs. Testing is then performed by using BoF's training module. The last procedure is to obtain the BoF based results for the prototype development.

B. Data Set in a Controlled Set-up

In this study,1300 images from the two kinds of Phaseolus Vulgaris Family Of Legumes namely the variety of "long bean" and "snap bean" were came from different vegetables vendors' location within the Region IV-A area. These images were captured in a controlled environment set-up using an Android mobile phone with a 16-megapixel camera on a white bond paper as a background for each sample image in uniform distant shots angles.

C. Image Pre-processing and Data Set Validation

ANN (Artificial Neural Network) is used for validating data set that fed in quality grading of snap beans (Baguio beans) and long bean (Sitaw) varieties cultivated in the Philippines using the BoF (Bag of Features) paradigm that can give as high as of 96.4% accuracy in a review paper of Bhargava & Bansal [13]. The images are pre-processed using the ANN machine running in a Matlab environment.

D. Data Set Features Extraction

The validated data set through the ANN method is used to be fed to a BoF machine for features extraction until the last stage of the framework.

The computed key points of SURF descriptors that as feature vectors were detected and described using the descriptors for each sample image.

E. Training and Classification

SVM in a multi-class level is utilized to perform the classification trained with the BoF model as binarized classifiers. BoF produced histograms instances from the training dataset are then processed by the trained SVM model [14].

F. Prototype Development

Building a prototype which utilizes the trained and validated methods of BoFs machine to integrate as a code library for snap beans and long bean varieties quality classifier is the end product of this paper. A framework is selected in building the said prototype in compiling the converted binary code to executable format application.

III.RESULTS

The results of the developed compiled binary prototype application make this whole endeavor compelling. The tables and graphs below are presented as the results of the study.

A. Data Set Pre-processing Method

The first phase of the study is the pre-processing of the captured images for generating and validating good data set using the ANN method. This validated data set is used as the core element in features extraction to quality classification using "bag of features" (BoF) technique.

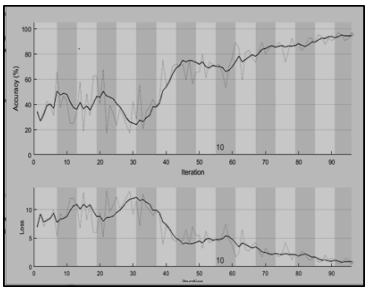

Fig.3Training graph report of captured images using ANN machine.

TABLE I:

ANN MACHINE ACCURACY REPORT

Epoch	Iteration	Time Elapsed (hh:mm:ss)	Mini-batch Accuracy	Mini-batch Loss	Base Learning Rate
1	1	00:00:20	34.38%	6.8935	1.00E-04
9	50	00:15:54	65.63%	5.4802	2.00E-05
16	96	00:30:10	95.31%	0.7473	8.00E-07

accuracy = 0.9504

Fig. 3 and Table I are the reports after going through to the pre-processing and training using the ANN method in the validation of images to form part of the new data set. The figures above present the result of 95% accuracy.

B. The BoF Results

The classifier BoF produced the necessary graphs, figures and tables that serve as evaluation and measurement of the outcomes of the entire study.

B.1 Confusion Matrix

The confusion matrix table that gives the true values from the 1300 images as sample data and accumulated 92.8% accuracy after going through the learning phase using the BoF method.

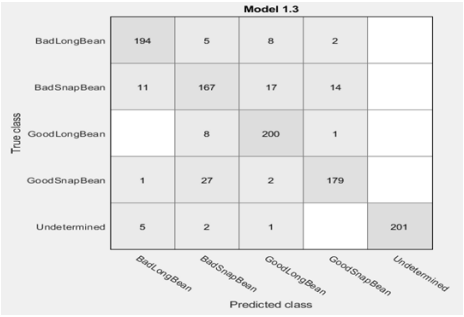

Fig.4 Actual Observation of Confusion Matrix

Fig.4 presents the actual number of images per category based on the predicted true positive, false positive, true negative and false negative values obtained from the Confusion matrix.

It can be observed that the highest true positive value is with the prediction of uncategorized (undetermined) class. Next is the good Sitaw bean with the highest confusion is between good and bad Baguio beans. Those without confusion are between good and bad Sitaw beans, undetermined and good Baguio beans, and between all the four classes and the undetermined class.

B.2 Visual Vocabulary from BOF Model

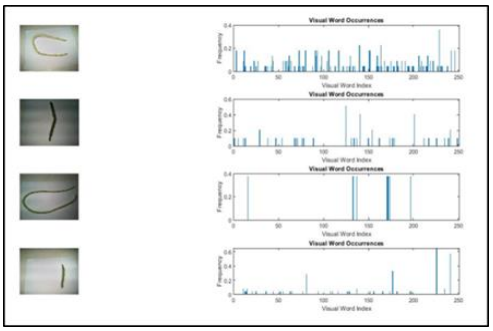

Fig.5. Histogram of the visual vocabulary of the study.

Fig. 5 is the visual vocabulary features occurrences of the four types of subject that shows the total number of each type of feature/word present in the training set in totality. It can be noted that occurrences in bad long beans have the most number that denoted of low true values in the matrix.

B.3The Snap and Long Beans Classifier (Prototype)

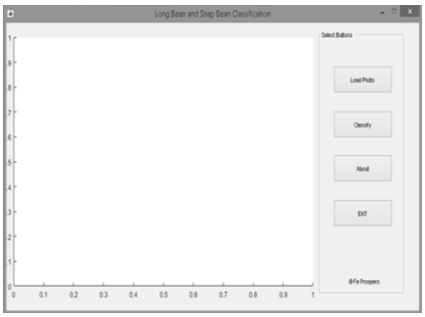

Fig.6The compiled binary application main menu.

Fig.6 shows the main menu of the compiled binary prototype application with two main features namely, the load photo and classify modules**.**

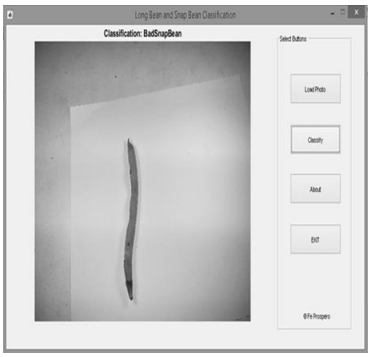

Fig.7 Sample GUI for the output of the prototype

Fig. 7 gives the result of the developed prototype which was compiled in binary executable format.

The *load photo* button enables the user to choose from saved files of captured photos in a controlled set-up already defined in the data set section. While the classify button enables to run the classifier to give the result that can be viewed in the upper part of the window.

V. CONCLUSION

This paper presents the viability of combining methods in determining the accuracy of the developed compiled application for quality classification of Long (Sitaw) and Snap (Baguio) beans from the family legumes commonly cultivated in the Philippines. However, the paper highly recommends acquiring more samples for the variety of legumes that can be found in the Philippines to increase the potential of obtaining higher accuracy of the outcome and to create an application using different platform such as mobile devices. The BoF machine in SVM environment as classifier gives a 90.2% accuracy using the cubic SVM classifier. The study highly suggests further expounding the undetermined class in the future. It will also further utilize the ANN and BoF in SVM environment as a classifier in a more concrete method by linking models directly to pipeline of the system as combination paradigms.

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AUTHORS PROFILE

Mirafe R. Prospero finished her Master of Science in Computer Science at Technological Institute of the Philippines – Manila. She has been an academician for more than two decades now and currently connected as assistant professor and program chair of Computer Studies Department of Lyceum of the Philippines University-Laguna. She has published several papers both for local and international publications. The latest paper publication is a Scopus indexed journal for International Conference on Control and Computer Vision (ICCCV 2018) of International Association of Computer Science and Information Technology Organization (IACSIT). She presented papers in the 17th (WCASET) World Conference on Applied Science Engineering and Technology under the umbrella of (IFERP) Institute for Engineering Research and Publication. She is also a mentor of several students' organizations and adviser/coach of winning computer contests for local, national and in the 2017 Microsoft Imagine Cup world competition that made her team number 8 among the 39 world finalists.

Bryan G. Dadiz is an assistant professor in Technological Institute of the Philippines - Manila; He received the award of an outstanding I.T. educator awarded by the Philippine Society of I.T. Educators (PSITE) on school year 2018-2019. He is an awardee for countless times as the Best Outcomes Based Teaching and Learning Educator in the years 2016-2018 in the institution where he is teaching. He is a graduate of Bachelors Degree of Computer Science in the Institution and also has received the Degree of Master in Information Technology at the same Institution. Presently, he is pursuing Ph.D. in Computer Science at De La Salle University – Manila. At TIP, he was awarded with college and university level recognitions for research, teaching and a trusted adviser of undergraduate students.