Development of Smart Sorting Machine Using Artificial Intelligence for Chili Fertigation Industries

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Abstract:
This paper presents an automation process is a need in the agricultural industry specifically chili crops, that implemented image processing techniques and classification of chili crops usually based on their color, shape, and texture. The goal of this study was to develop a portable sorting machine that will be able to segregate chili based on their color by using Artificial Neural Network (ANN) and to analyze the performance by using the Plot Confusion method. A sample of ten green chili images and ten red chili images was trained by using Learning Algorithm in MATLAB program that included a feature extraction process and tested by comparing the performance with a larger dataset, which are 40 samples of chili images. The trained network from 20 samples produced an overall accuracy of 80 percent and above, while the trained network from 40 samples produced an overall accuracy of 85 percent. These results indicate the importance of further study as the design of the smart sorting machine was general enough to be used in the agricultural industry that requires a high volume of chili crops and with other differentiating features to be processed at the same time. Improvements can be made to the sorting system but will come at a higher price.

Keywords: *Precision Agriculture, Artificial Neural Network, Smart Fertigation*

1. Introduction

A sorting process that is automated with the use of a control system will not only make the process simple and precise but also reliable to be used as a machine [1]. This is because an automatic sorting machine has the purpose to replace the basic function of the human vision, thinking, and actuate for sorting operation [2]. It has many possible uses in the food processing industry especially fruits and vegetable products such as chili to be sorted based on their differentiating features such as color, shape, and texture [3]. However, to automatically inspect and classify the chili accurately and effectively, the normal use of simple controllers and sensors without the ability to learn and predict the outcome will not be effective enough to handle the required task [4].

One way to automatically classify chili and to achieve an accurate result is to use artificial intelligence with the help of machine vision [5], [6], [7]. Chili can be classified based on their color by using Artificial Neural Network (ANN) and the image captured simply by using a smartphone camera [8]. Other studies also decided to use ANN as the fruits and vegetable classifier having a variety of colors [9], [10], [11]. However, past studies only focus on the segregation process of dried red chili and the maturity level of the chili. Few studies have been made for the classification of fresh chili and in real-time application [12], [13].

This study presents a design for the classification of fresh chili based on color for real-time application and implementation of the system by using a sorting machine. By using the image processing technique for the preparation of feature extraction, the data can be trained using ANN in MATLAB and tested. The chosen method for this study proven in two ways, using plot confusion to confirm the accuracy of the trained network and also by analyzing the plot receiver operating characteristic curve to confirm the performance of the trained network.

2. Literature Review

A system for sorting most common usage is to classify a batch of objects such as chili based on the desired condition. This can be various types of sorting variables such as sort based on color, shape, size or even defect feature.

2.1. Mechanism

A previous study designed a strategy to sort objects at high speed by using a Delta robot [14]. The design included a vision module using a CCD camera for grabbing the image of the objects to be processed and object tracking purposes by using a servo motor that sends the position pulse data to the system. The second module was motion control that controlled the speed of the conveyor for 400 millimeters per second and 120 sorting tasks per minute of the Delta robot. The proposed strategy worked efficiently for only two different pieces of the object.

To segregate objects efficiently especially for small size objects such as rice grain or chili, a vibrating could also be used. However, from the previous studies, the sorting process was only able to separate unwanted products from the rest without any other differentiating features [15,16]. A system with multiple features to differentiate will be a bit complex. This is shown in

a study, where a system designed to sort sweet tamarind into three different classes of size using three pneumatic segregator and defective factor to the end line of the product stream [17]. The important feature that this study was missing was the color trait for the product.

2.2. Control System

There are various methods for controlling a sorting machine system [18, 19, 20, 21]. The most common basic controller for this purpose can be by using ARDUINO controller, Peripheral Interface Controller (PIC) microcontroller, Raspberry Pi, or even Programmable Logic Controller (PLC). ARDUINO has been used for many various purposes such as robotic contest implementation, robotic devices control system with the implementation of Pulse Width Modulation (PWM), and complicated tasks such as controlling various types of sensors monitoring and vision modules [22], [23], [24]. For automation of sorting system, ARDUINO controller has been used to control three conveyor system that consists of dc motor, stepper motor and servo motor [25]. Besides that, another study suggested that a sorting system based on color by using the ARDUINO microcontroller will prove high efficiency with low cost [26].

2.3. Digital Image Processing

Since digital image can be represented in matrix form, therefore MATLAB should be ideal for image processing as MATLAB has the computing ability of matrix-oriented operations. There is four basic image type that MATLAB support which are index image, gray image, RGB image and binary image [27,28]. The most common digital image operations that can be run by toolboxes in MATLAB including Morphological operation, Histogram equalization, Discrete Fourier and Cosine Transform (DFT and DCT), Image Denoising Filters and lastly Edge Detection operation which include Sobel operator and Prewitt operator. The purpose of the process of image processing is to prepare the digital image for further processing or to extract the valuable feature from the original image. Fig. 1 shows the block diagram of a digital image process system.

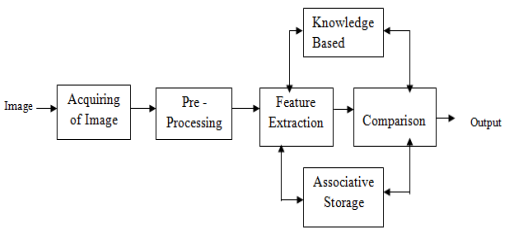

Fig. 1. Digital Image Process System [29]

2.4. Artificial Intelligence

Artificial intelligence (AI) is a field in computer science for making a machine with the intelligence that has the computational ability in a similar way of human brain works. Some of the applications of AI include computer vision, speech recognition, understanding the natural language, and also heuristic classification [30, 31]. Machine learning which is one of the branches of AI had already grown quickly in almost all technical fields that utilized the usage of computer science and statistics for commercial use as well as in industries [32]. The most common four types of learning in this field are Supervised Learning, Unsupervised Learning, Semi-Supervised Learning, and Reinforcement Learning. The categories which fall upon this field are as shown in Fig. 2.

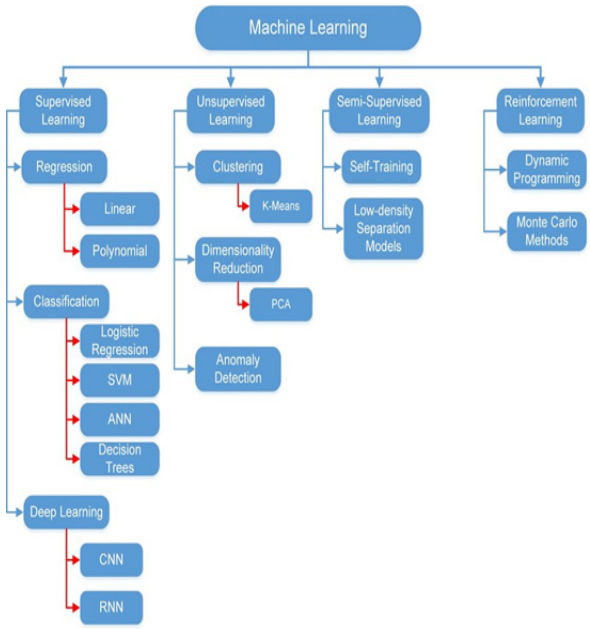

Fig. 2. Machine Learning Categories with Different Algorithms [33]

Supervised Learning is the process in which the learning process takes the inputs and the expected outputs to be considered in the calculation and analyzing process. Then, the desired output can be obtained. Therefore, the accuracy of the calculated output will improve and becomes closer to the desired output. The purpose of Supervised Learning is to conclude the function or mapping of training data in a labeled format [34]. The system will be given an input data of vector x which is the training data and also desired output labeled as y which is a function of input data that is yet to be determined. An output vector y is a description of each respective input example from input vector x. By combining these two labeled data, a training model can be formed [35].

The process of labeling output vector y is to be done manually for each training example present in the training data. The implementation of Semi-Supervised Learning is used normally when the labeled data points are of a limited amount while there are a lot of unlabeled data points in the datasets. Both labeled and unlabeled data points will be used by the system to generate a better learning model. Reinforcement Learning is used when less information is available to the model by trial and error to determine the output that gives higher rewards to the system [36]. The Unsupervised Learning will have no known output for the model, only provided with the inputs

labeled as vector x. The algorithm will then calculates and makes an analysis based on the patterns in training data to predict the output. The categories under this type of learning are clustering, dimensionally reduction, and anomaly detection.

3. Design

There are different types of sorting mechanisms as previously discussed. There is a sorting mechanism that used pneumatic or hydraulic to segregate the products, using Delta Robot, sorting tray using stepper or a servo motor, and also multiple air blowers as in industrial applications. For this system, a stepper motor was chosen as it can be moved precisely and accurately based on the design requirement. A 12V stepper motor will be driven by a motor driver ULN 2003 that is normally used as a driver circuit for relays, LED lighting and stepper motor [37, 38]. The microcontroller, ARDUINO Uno was to control both the power window and stepper motor It will receive its supply from a portable laptop that was set up to include a MATLAB program for image processing. A Camera Module OV7670 VGA that interfaced with the ARDUINO was used to capture the chili image. A setup for the MATLAB program will then processed the image retrieved from the saved folder of the image captured using the VGA camera [39, 40, 41].

Classification of chilies can be implemented by using an appropriately designed pathway. Fig. 3 contained the information for the process of classification of chili.

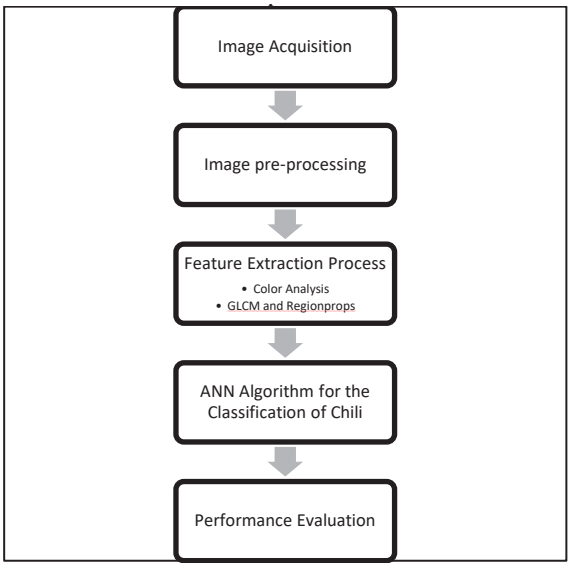

Fig. 3. Flowchart of the Designed System

For automation of sorting system, ARDUINO controller has been used to control three conveyor system that consists of dc motor, stepper motor and servo motor. Besides that, a sorting system based on color by using the ARDUINO microcontroller will prove high efficiency with low cost. Fig. 4 showed the flowchart of the sorting mechanism process.

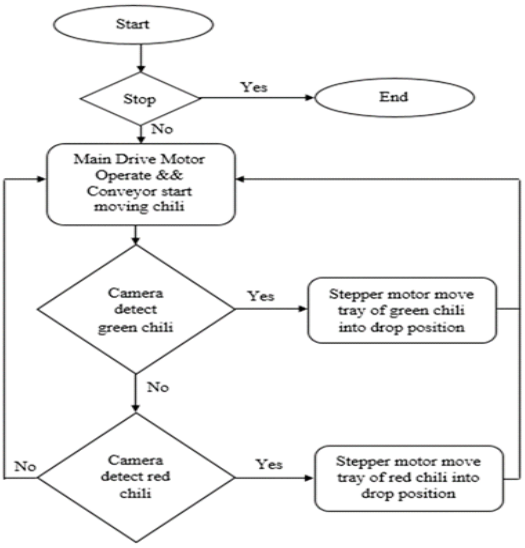

Fig. 4. Flowchart of the Sorting Mechanism

To simplify the design process, a block diagram that presents the overall system was developed as shown in Fig. 5. It can be seen that ARDUINO will act as the main controller for the task. A camera module acted as the sensor for this operation. MATLAB software that included ARDUINO Toolboxes was programmed to process the image and classify the chili. The stepper motor will move the sorting tray of the chili based on their color by using the signal received from ARDUINO.

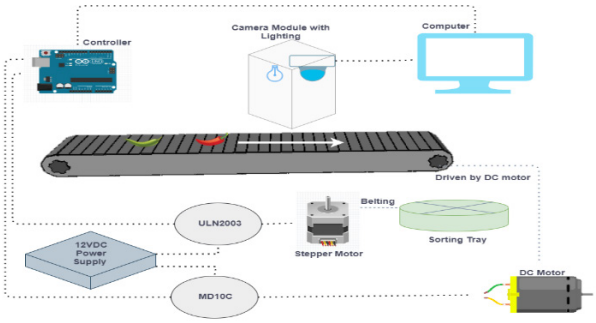

Fig. 5. Illustration of the Overall System

4. Implementation

Image pre-processing is a crucial process as it can aid in providing more detailed information for the feature extraction process. This process helps in the improvements of the image.

4.1. Image Acquisition

Images of chili will be used as the input data for this project. The images were taken from the real-world image of the chili samples from the conveyor band by using the VGA camera module. The image of the chili will then be used as the training dataset and testing dataset. The chili images taken will then be cropped into the region of interest (ROI).

4.2. Image Cropping

The raw image taken by the CCD camera will be cropped to a specific region needed for classification. Raw images were then cropped to extract the region of interest (ROI) in a rectangular format from the original image. The cropped image will include the chili in the image and also the background which was the conveyor band in this case. This process was done by specifying the rectangle coordinate for cropping the image. Therefore, further processing can be focused on the intended object in the image which was chili.

4.3. Image Resize

Image resizing is important since the cropped image can be too big in size dimension. Therefore, when all images have a similar size, it will assist the feature extraction process. This process will also help in fasten up the image processing time.

4.4. Color Conversion

This process will convert the image into CIE lab color space using a simple command in MATLAB which was rgb2lab. Digital images are a combination of red, green, and blue (RGB) colors that have three separate luminance values for each pixel. Therefore, this process will convert the RGB white value to L*a*b to bring more details into the data. The image will then be converted into grayscale after the masked image was produced. This was done by using a command in MATLAB, rgb2gray. The process then continued for image sharpening.

4.5. Color Segmentation

This process was done by using Color Thresholder Application inside the MATLAB toolbox. The application allows the user to set the segmentation ratio which was represented by value L and for this process the value was set to 1 to segment chili from the background. Also, the contour was adjusted to have smooth images. The segmented images then were created and known as masked images.

4.6. Image Sharpening

Image sharpening enhances the edges and fine details of an image. The contrast of the image between light and dark areas can be increase to enhance the features of the images. High pass filters was the method used to sharpen the image so that it will be easier to extract the feature of the image. It can be called out in MATLAB by the 'imsharpen' function.

4.7. Color Extraction

Colored images normally consist of RGB values, and the mean for each value inside the image is very useful especially in machine learning. This process was done for extracting the color components of RGB. The dynamic range for every pixel presents in the images can be normalized by finding the mean of the RGB values. The standard deviation was calculated because it contains the contrast information of the image. A high value of standard deviation shows that the contrast of the image histogram was high while a low standard deviation value shows otherwise. These statistical findings will allow the algorithm used in this project which was the ANN algorithm to train faster and perform better accuracy for the classification.

$$Mean, \mu = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{1}$$

$$Standard\ deviation, \sigma = \frac{1}{N}\sum_{i=1}^{N}(x_i - m)^2 \tag{2}$$

4.8. Performance Evaluation

The performance of ANN can be analyzed using the Confusion Matrix. This is a table that contains the summarized result of classifier prediction. The values of correct and incorrect prediction can be recorded [62]. From the confusion matrix, the system performance can be evaluated by four specifications which are accuracy, specificity, sensitivity, and precision of classification task. The formulas for these values can be expressed as:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{3}$$

$$Sensitivity = \frac{TP}{TP + FN} \tag{4}$$

$$Specificity = \frac{TN}{TN + FP} \tag{5}$$

$$Precision = \frac{TP}{TP + FP} \tag{6}$$

5. Results and Discussion

5.1. Analysis of Variance (ANOVA)

This test is to assess the potential difference between 2 or more categories between the variables. In this case, the test conducted was to measure the difference between the mean level of the red and green index value of RGB for the green and red chili. The result is shown in Fig. 6. Green chili had a mean value of 8.2 for the green parameter index, which was higher than the mean for red chili. For the red parameter index value, the red chili had a higher mean value than the green chili. Therefore, there exist statistically significant differences between red and green chili.

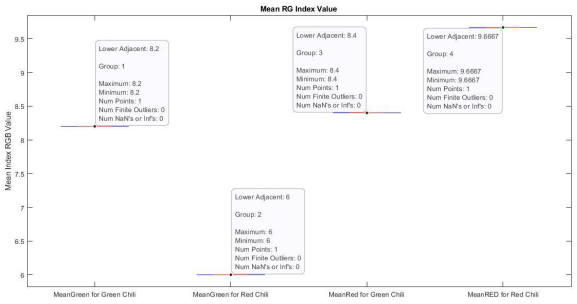

Fig. 6. ANOVA Test for Red and Green Chili

5.2. Artificial Neural Network (ANN) Model Network

The MATLAB program that was chosen for this project was pattern recognition. It can be done manually by training the data using a pattern recognition tool in MATLAB or by including the parameters of the program in the coding. The architecture of ANN is such that the number of input features for each data point has the same number of nodes of the input layer. The hidden layer of the architecture or the number of nodes is set to ten hidden layers as it is user-defined. The number of nodes in the output layer corresponds to the number of classes (targets), which were also pre-defined in the MATLAB coding. For this project, the number of targeted outputs was set for two classes, red and green chili. The block diagram of the network is shown in Fig. 7.

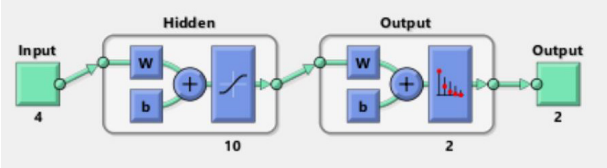

Fig. 7. Block Diagram of ANN Model

5.3. Performance Validation

Generally, the error reduces after more epochs of training, especially the train data will keep on decreasing until validation data hit the best performance, meaning reaching the lowest possible Mean Square Error (MSE). However, the validation data might start to increase after reaching the best performance, indicating that the network starts overfitting the training data. In the default setup, the network model will stop training the data after producing six consecutive increases or validation errors after reaching the lowest MSE, represented by the green line. The best performance was taken from the epoch with the lowest validation error.

The performance of the trained network for 20 samples of chili images was 0.232 at epoch 8 as shown in Fig. 8. After hitting the best performance, the three-line which are train, validation, and test data start to pass away from the dotted line (best performance line), indicating that divergence has occurred. After retraining the network several times, this divergence still occurred during the process, it showed that the performance of the model network did not work well with the number of chili images samples that have been chosen.

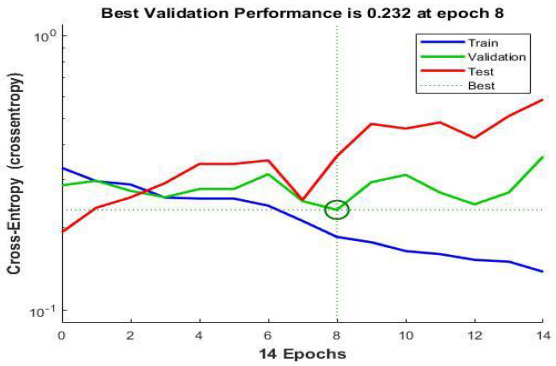

Fig. 8. Performance Validation Graph of 20 Chili Images Samples

The best validation performance of the trained network for 40 samples of chili images was 0.042121 at epoch 20 as shown in Fig. 9. After hitting the best performance, the three-line which are train, validation, and test data tend to maintain the line near the dotted line (best performance line), indicating that convergence has occurred. After retraining the network several times, this convergence still occurred during the process, it showed that the performance of the model network did work well with the number of chili images samples that have been chosen.

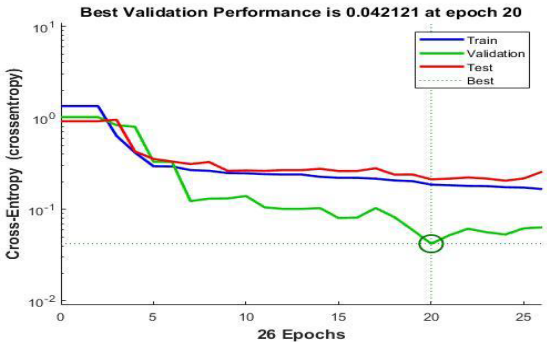

Fig. 9. Performance Validation Graph of 40 Chili Images Samples

5.4. Comparison Between Model Network Trained with 20 Samples and 40 Samples Performance

The accuracy of the ANN classifier when the network was trained with 40 samples of chili images was better than when using 20 samples. This shows that a higher number of samples used for training the network has an effect on the efficiency in classifying the chili. In addition, it also predicts more cases correctly even though the number of samples was higher. Hence, the model network was more reliable to be used for

further application such as for the use in a real-time situation. Besides, the time taken for both network model situations to be trained were about the same with only a difference of 0.01 second. The comparison for the performance of the model network was shown in Fig. 10.

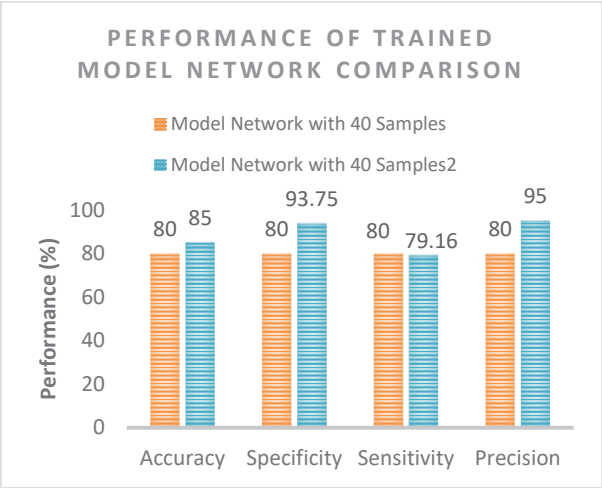

Fig. 10. Performance of Trained Model Network Comparison

6. Conclusion

The process of constructing a sorting conveyor in this study takes place from scratch and by using inexpensive materials Furthermore, the important steps in building a classification model network using ANN have been elaborated in this thesis. Therefore, it is clear that image pre-processing is a crucial step for further processes to take place in classifying the chili. Proper image processing methods will help to perform a feature extraction process on the image for the classification. Color analysis on the chili image was done to extract the color of the chili by measuring the components of the RGB mean value. These results of extracted features are then being fed as the input for the ANN classifiers. The performance of the trained model network is then compared for a model network using 20 samples of chili images and 40 samples of chili images to find the optimum parameter that affects the overall efficiency in classification.

Based on the result, both performances of the model network when using 20 samples and 40 samples of chili images were good. The model network should be tested with a larger dataset to improve the effectiveness and reliability of the classifier. Therefore, these findings showed that the overall accuracy of the network for 40 samples was 85%, which was better than the network trained with 20 samples that had an overall accuracy of 80%. By using a larger dataset that used 40 samples of chili images instead of 20 samples, the classifier will also have a higher number of samples for testing and validation of the model network. Hence, the trained network is more reliable for further application as more data were being trained while maintaining the performance. T

In conclusion, a deep understanding of the processes of constructing a sorting conveyor belt has been provided. For the chili classification, the program was designed by using MATLAB software. The program included the image pre-processing, the feature extraction process, and the ANN model network as a pattern recognition classification. The techniques and methods proposed in this study need to be improved as the performance of the classifier can still be enhanced. For future research, the classification of the chili images can be done by using other types of classifiers such as Support Vector Machines (SVM), or other branches of machine learning such as clustering by using K-means value. Based on the results, the feature extraction methods could also be improved to achieve a higher percentage of accuracy. The color of the chili images could also be extracted by using CIE lab color spaces, or other spaces such as HSV and HSI. By measuring these color indexes and their statistical value, a more accurate threshold can be established. The performance of the classifier also being affected by the quality of the camera that has been used. Thus, by using a higher-quality camera, a clearer chili image can be obtained for processing and color extraction. Lastly, the Gray Level Co-occurrence (GLCM) and Regionprops can be used to determine the shape, texture, and size of the chili. Therefore, the chili can be classified into much more classes depending on the application.

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