Journal of Engineering and Technology

CHILI CROP SEGREGATION SYSTEM DESIGN AND DEVELOPMENT STRATEGIES

M. F. Abdul Aziz[1], W. M. Bukhari[*1], M. N. Sukhaimie[2], T. A. Izzuddin[1], M. A. Norasikin[1], A. F. A. Rasid[1], N. F. Bazilah[1]

[1]Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[2]Melor Agricare PLT, MK 18 Kg Padang, 78000 Alor Gajah, Melaka, Malaysia.

*bukhari@utem.edu.my

Abstract— 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 review the development of a portable sorting machine that will be able to segregate chili based on their color. Digital Image Processing (DIP), which is a crucial part to perform the Feature Extraction process was discussed with the elaboration of steps to execute the DIP process. Besides, the analysis of different methods to extract the chili color based on the RGB color component was included. This paper focused more on the Machine Learning (ML) technique, which is the main component of

Artificial Intelligence. The image data taken from chili samples can be trained by using Learning Algorithm in the MATLAB program. The performance of the trained network then can be evaluated by using the Confusion Matrix technique. The methods that have been reviewed in this paper were 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.

I. 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 is proven in two ways, using plot confusion to confirm the accuracy of the trained network and also by manually counting the number of chilies that have been correctly classified by the sorting machine.

II. Previous Works
A. 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 millimetres 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 factors to the end line of the product stream [17]. The important feature that this study was missing was the color trait for the product.

B. 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].

C. Image Acquisition

There are two main digital cameras used for basic image processing purposes and also high-performance applications due to low noise features. Both Charged-Coupled Device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) act as a sensor for the input of image format [27]. An article by Baumer Ltd stated that the main key difference between CCD cameras and CMOS cameras is that they operate differently in terms of the way each frame is captured. The CCD camera is described as a current-driven device known as a global shutter while CMOS is described as a voltage-driven device known as a rolling shutter [28]. The article also provided the criteria for selecting the suitable camera type based on the usage which is the area scan and line scan. With both cameras have a slight difference in cost, CCD camera will give better image reproduction or fidelity, uniformity, shuttering, and dynamic range but at the cost of a lower speed of operation, while CMOS will be able to

operate at high speed, windowing and has natural blooming but at the cost of lower image quality [29].

D. Digital Image Processing (DIP)

Since digital images 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 [30]. 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 [31]. 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. Figure 1 shows the block diagram of a digital image process system.
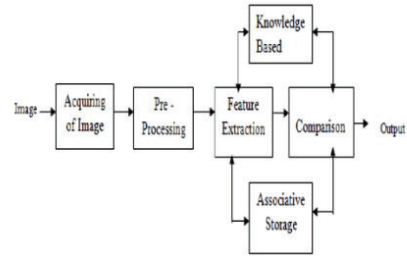

Figure 1: Important Stages in Digital Image Processing System [32]

E. Color Analysis

Color analysis is a relevant method to extract data of an object by the image segmentation method. The color feature can be differentiated by the intensity and chromaticity of the color. Color also can be uniquely specified by a coordinated system of three dimensions or by a subspace of a system in a color space. Several color spaces used by the graphic algorithm are RGB (red, green, and blue) space, CMYK (cyan, magenta, and black), and CIELAB or known as CIE L*a*b. There are cylindrical components to represent the RGB model points of color that are HSV (hue, saturation, and value) space, HSI (hue, saturation, and intensity) space [33, 34, 35, 36, 37].

From a previous study, a few samples of green, yellowish, and orange Habanero chilies were examined from day one until day fifteen to detect color changes during the ripening of the chilies [38]. This research was done by identifying the region of interest (ROI) to establish the criterion for the segmentation process that defined the texture and colorimetric parameters. Thus, CIELAB with the implementation of hue angle threshold was the suitable algorithm that was used to analyze the color changes. This was done by converting the CIE L*a*b color space of the image from the RGB color space [39]. RGB value could also be used for the image segmentation process to recognize apple [40]. RGB component proved to extract more image pixels than a single component. However, this method was tested only on the red color of apples. Another color analysis study made in 2020 used Index Pixel Algorithm to detect the maturity level of chili by observing the color changes of the chili from green to orange and bright red to darker color [41]. Learning vector quantization (LVQ) was chosen to classify the index pixel data into RGB groups before summarized into plot confusion. The results showed that the percentage of the epoch tables were all above 90 percent indicating a successful attempt was done.

F. Artificial Intelligence (AI)

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 heuristic classification [42, 43]. Machine learning (ML) is one of the branches of AI. ML 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 [44]. 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 Figure 2. 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 labelled format [46]. The system will be given an input data of vector x which is the training data and desired output labelled 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 labelled data, a training model can be formed [47].

The process of labelling 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 labelled data points are of a limited amount while there are a lot of unlabelled data points in the datasets. Both labelled and unlabelled 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 [48]. The Unsupervised Learning will have no known output for the model, only provided with the inputs labelled as vector x. The algorithm will then calculate 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.
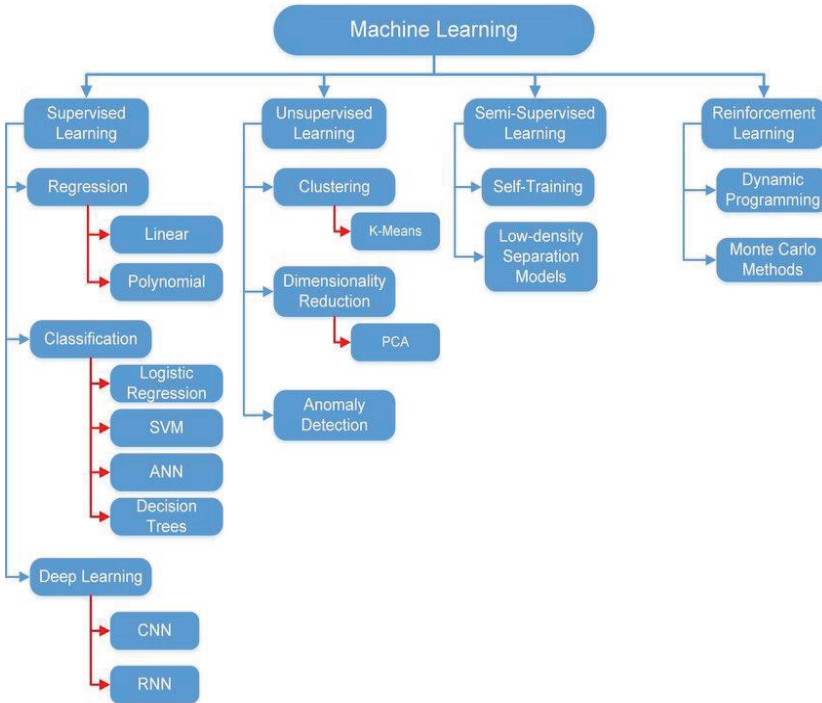
Figure 2: Machine Learning Categories with Different Algorithms [45]

III. System Flowchart

Classification of chilies can be implemented by using an appropriately designed pathway. Figure 3 contained the information for the process of classification of chili while Figure 4 shows the flowchart of the sorting mechanism process.
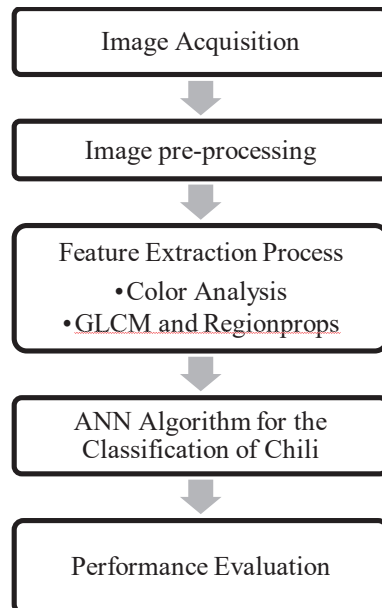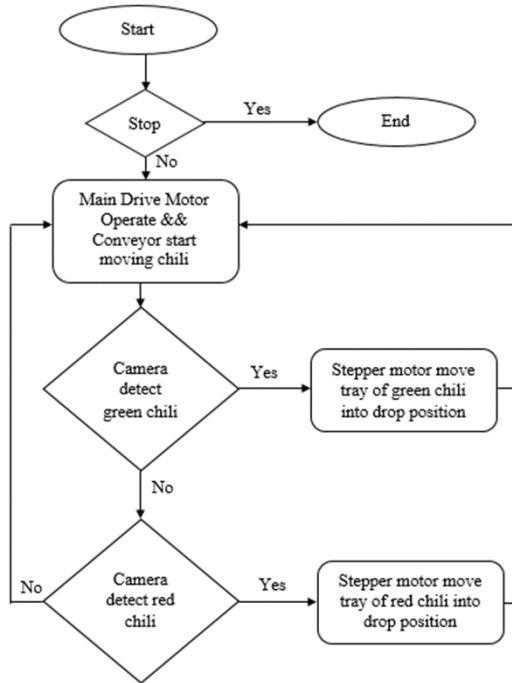

Figure 3: Flowchart of the designed System

Figure 4: Flowchart of the sorting mechanism

IV. Design

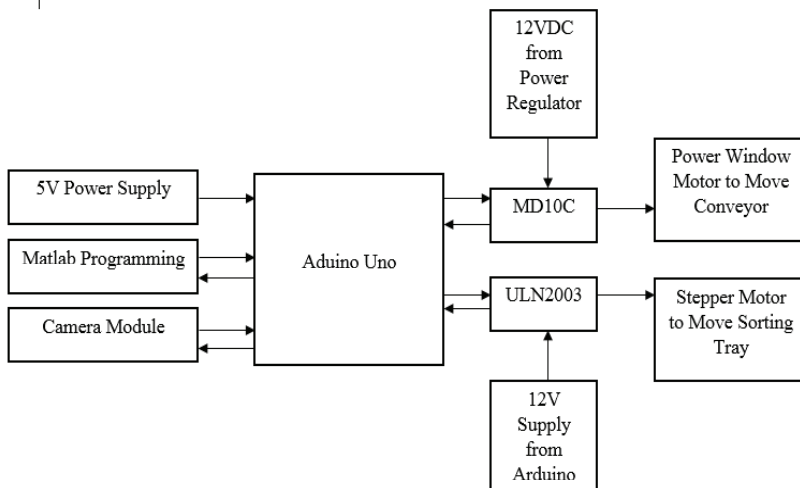The overall system design was developed as shown in Figure 5.

Figure 5: Block diagram of the overall system for controlling conveyor motor, sorting motor, and camera module

V. Equipment

To design a sorting conveyor machine, the required pieces of equipment were the driving components to move the product into the sorting system, a camera module with lighting, the components for the selected sorting mechanism, and the main controller to control the whole operation.

The design and criteria of a sorting machine must be considered before deciding the equipment to be used. If the sorting machine design included a conveyor to move chili, therefore a dc motor or an ac motor can be used to drive the system. Besides, for a sorting machine that only moving and sorting chili in low quantity, a low-end specification of the motor can be chosen. For example, a power window motor is suitable for a small-sized machine. This is because the rated torque of the power window motor is about 20 to 30 kilogram-force centimeters (Kgf. cm) or 2.9 Nm and inexpensive [49]. To control the operation smoothly and automatically, the conveyor motor needs to be controlled by a microcontroller.

For a high-power motor that requires a large current or voltage, a motor driver will be required. Considering the power window motor as an example, the input voltage should be 12-volt direct current (VDC) and the input current of 10 ampere (A). Therefore, the power supply for this motor will need a power regulator that converts 220~240 AC into a stable 12 VDC and 10 A for the power requirement of the power window motor. To control the operation smoothly, a motor driver that can handle the high-power requirement of the power window motor was needed [50, 51, 52]. The compatibility of each selected device is then confirmed before any progress to be made. Table 1 shows an example of the compatibility of the devices.

The speed of the conveyor can be calculated using the specification of the power window.

Table 1: Validation of Compatibility Between Devices

Parameter	Power Window Motor	Motor Driver	Power Regulator	Compatibility
Operating Voltage	12VDC	5V~30V	Output 12VDC	Compatible
Rated current	5A~15A	13A	10A	Compatible
Peak current	28A	30A	Not available	Compatible

$$v \ (m/s) = \frac{z*t*n}{60} = \frac{18*(12.7*10^{-3}m)*60rpm}{60s} = 0.2286(m/s) \qquad (1)$$

where,

v = Chain speed in meter per second (m/s)

z = Number of teeth = 18T

t = Drive chain pitch (mm) = 12.7mm

n = Rated speed of the power window motor = 60±15 RPM

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 multiple air blowers as in industrial applications.

For a system designed as shown in Figure 6 as an example, 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 [53, 54]. 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 [55, 56].
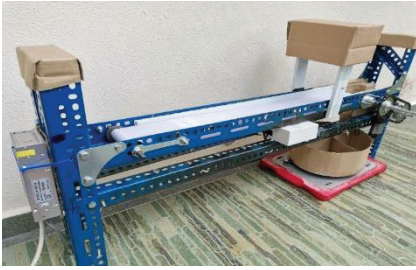
Figure 6: Complete setup of sorting conveyor for chili

VI. Image Processing

For extracting the required information of the image correctly, the image pre-processing method should be used. 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. Figure 7 shows the step flow of image pre-processing.
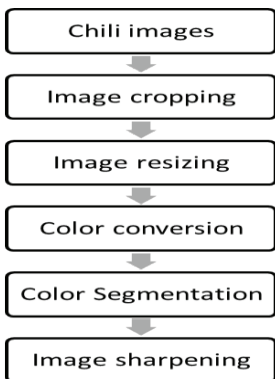

Figure 7: Image pre-processing steps

A. Image Acquisition

The chili images were taken from the real-world image of the chili samples from the conveyor band by using the camera module. The image of the chili will then be used as the training dataset and testing dataset. A total of 10 images of green chili and 10 images of red chili will be taken and then will be cropped into the region of interest (ROI). The data collected consists of chili in different colors and shapes.

B. 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 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.

C. 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.

D. Color Conversion On The Image

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 convert 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.

E. 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.

F. Image Sharpening

Sharpening enhances the edges and fine details of an image. The contrast of the image between light and dark areas can be increased to enhance the features of the images as shown in Figure 24. High pass filters were 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.

VII. Feature Extraction
A. Color Extract

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 presented 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.

$$\text{Mean}, \mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (2)$$

Standard deviation,
$$\sigma = \frac{1}{N}\sum_{i=1}^{N}(x_i - m)^2 \qquad (3)$$

B. GLCM

The Gray Level Co-occurrence (GLCM) method was used to extract the texture feature of the images. Both GLCM and the Regionprops methods were used to train the network the feature of the chili that will be classified in this project. These were also useful additional information that can prevent the learning algorithm to process a wrong input taken by the camera and besides will also improve the classifier performance. GLCM will determine the brightness value frequency of pixels combination usually in pairs. These values will be represented as a matrix, denoted as ($m×n$), with rows and columns which represent the number of gray levels in the image [57]. The normalized GLCM entries is expressed by:

Normalized GLCM entries,
$$p(i,j) = \frac{p(i,j)}{mxn} \qquad (4)$$

The GLCM mean and standard deviation are calculated as follows:

GLCM mean by row,
$$\mu_x = \sum_{i=1}^{m}\sum_{j=1}^{n} i, p(i,j) \qquad (5)$$
GLCM mean by column,
$$\mu_y = \sum_{i=1}^{m}\sum_{j=1}^{n} j, p(i,j) \qquad (6)$$
GLCM standard deviation by row,
$$\sigma_x = \sum_{i=1}^{m}\sum_{j=1}^{n}(i - \mu_x)^2, p(i,j) \qquad (7)$$
GLCM standard deviation by column,
$$\sigma_y = \sum_{i=1}^{m}\sum_{j=1}^{n}(j - \mu_y)^2, p(i,j) \qquad (8)$$

C. Regionprops

The shape features of the image can also be extracted. The shape feature is the representation of image geographic properties. Hence,

the Regionprops method was used. The main focus for this method was to get the area, perimeter, eccentricity, minor axis length, and major axis length of the image features [59]. Many other different properties could also be extracted by using this method as stated in the official online Mathworks course. The selected features can be called out by using the MATLAB command [58]. An example to extract area and eccentricity information is by using the following code:

```
stats = regionprops
(BW, 'Area', 'Eccentricity');        (9)
```

VIII. Artificial Neural Network (ANN)

ANN is a computational network that imitates the decision process of the human central nervous system. This system can learn new things as well as adapting environmental changes [59, 60]. The output from the features extraction process will be the input vector of the ANN structure. This input data then will be learned by the hidden layer before sending the result to the output layer. The

transfer function that has been chosen for this project is the sigmoid function. The sigmoid function will produce output in the range of 0 and 1. It is similar to the step function by using a sigmoid function where $\sum \mathbf{x}$ is the sum of the inputs [61]:

$$f(\textstyle\sum x) = \frac{1}{1+e^{-\sum x}} \qquad (10)$$

Forward propagation is a process of propagating the attribute values from the network's input to its output. Mean square error (MSE) was used to determine the rate of error of the forward propagation process during the training process. Therefore, the element difference between the output and the target vector can be determined. Lastly, the algorithm was fed with the backpropagation method. The purpose of this step was to find the optimum weight for the optimization of classification performance by calculating the gradient error function wrt the weights. The functions are defined as:

$$y_i = f(\textstyle\sum_j w_{ji}{}^{(1)} f(\textstyle\sum_j w_{kj}{}^{(2)} x_k)) \qquad (11)$$
$$MSE = \frac{1}{m}\textstyle\sum_{i=1}^{m}(t_i - y_i)^2 \qquad (12)$$

IX. 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:

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \qquad (13)$$

$$\text{Sensitivity} = \frac{TP}{TP+FN} \qquad (14)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \qquad (15)$$

$$\text{Precision} = \frac{TP}{TP+FP} \qquad (16)$$

X. Conclusion

This paper presented a comprehensive review of the literature regarding the development of a sorting machine that requires an ARDUINO Uno microcontroller for automation purposes. The suitable methods for processing the image to enhance and to improve the image for the feature extraction process were also discussed that included image cropping, resizing, sharpening, and segmentation by color. Color analysis, GLCM, and Regionprops technique were elaborated as the method to extract specific features of chili images. The classification method that used ANN was also discussed as well as Plot Confusion to test the performance of the system.

XI. Acknowledgments

XII. References

[1] K. W. Moe, M. N. Aye and T. A. Daw, "Automatic Sorting Machine," *International Journal of Science and Engineering Applications,* vol. 7, no. 8, pp. 138-142, 2018.

[2] J. M. Low, W. S. Maughan, S. C. Bee and M. J. Honeywood, "Sorting by color in the food insdustry," in *Instrumentation and Sensors for the Food Industry*, Elsevier, 2001, pp. 117-120.

[3] J. A. Kodagali and S. Balaji, "Computer Vision and Image Analysis based Techniques for Automatic Characterization of Fruits A Review," *International Journal of Computer Applications,* vol. 50, no. 6, pp. 6-12, 2012.

[4] A. Stefano and M. D. Bini, "Artificial Intelligence, Machine Learning, Deep Learning, and Cognitive Computing: What Do These Terms Mean and How Will They Impact Health Care?," *The Journal of Arthroplasty,* vol. 33, no. 8, pp. 2358-2361, 2018.

[5] O. Cruz-Domínguez, J. Carrera-Escobedo, C. Guzmán-Valdivia, A. Ortiz-Rivera, M. García-Ruiz, H. Durán-Muñoz, C. Vidales-Basurto and V. Castaño, "A novel method for dried chili pepper classification using artificial intelligence," *Journal of Agriculture and Food Research,* 2021.

[6] V. Kakani, V. Huan Nguyen, B. P. Kumar, H. Kim and V. R. Pasupuleti, "A critical review on computer vision and artificial intelligence in food industry," *Journal of Agriculture and Food Research,* vol. 2, 2020.

[7] M. Sofu, O. Er, M. Kayacan and B. Cetişli, " Design of an automatic apple sorting system using machine vision," *Computers and Electronics in Agriculture,* vol. 127, pp. 395-405, 2016.

[8] N. Khuriyati, D. A. Nugroho and N. A. Wicaksono, "Quality assessment of chilies (Capsicum annuum L.) by using a smartphone camera," in *IOP Conference Series: Earth and Environmental Science*, 2020.

[9] H. Opeña and J. P. Yusiong, "Automated Tomato Maturity Grading Using ABC-Trained Artificial Neural Networks," *Malaysian Journal of Computer Science,* vol. 30, pp. 12-26, 2017.

[10] R. F. Mrs, S. Thomas, M. Isabel and B. Hannah, "Identification Of Ripe And Unripe Citrus Fruits Using Artificial Neural Network," *Journal of Physics Conference Series,* vol. 1362, p. 012033, 2019.

[11] F. Mazen and A. Nashat, "Ripeness Classification of Bananas Using an Artificial Neural Network," *Arabian Journal for Science and Engineering,* vol. 44, 2019.

[12] M. Ataş, Y. Yardimci and A. Temizel, "A new approach to aflatoxin detection in chili pepper by machine vision," *Computers and Electronics in Agriculture,* vol. 87, pp. 129-141, 2012.

[13] W. H. M. Saad, S. A. A. Karim, S. A. Radzi and Z. M. Yussof, "Classification and detection of chili and its flower using deep learning," *Journal of Physics: Conference Series,* vol. 1502, p. 012055, 2020.

[14] W. Zhang, J. Mei and D. Y., "Design and Development of a High Speed Sorting System Based on Machine Vision Guiding," *Physics Procedia,* vol. 25, pp. 1955-1965, 2012.

[15] K. Akila, B. Sabitha, K. Balamurugan, B. K. and T. Ashwin Gourav, "Mechatronics System Design for Automated Chilli," *International Journal of Innovative Technology and Exploring Engineering (IJITEE),* vol. 8, no. 8S, pp. 2278-3075, 2019.

[16] J. Camacho, R. Lewis and R. S. Dwyer-Joyce, "Wear of a chute in a rice sorting machine," *Wear,* vol. 263, no. 1-6, pp. 65-73, 2007.

[17] B. Jarimopas and N. Jaisin, "An experimental machine vision system for sorting sweet tamarind," *Journal of Food Engineering,* vol. 89, no. 3, pp. 291-297, 2008.

[18] S. M. Sheth, R. K. Kher, R. Shah, P. Dudhat and Jani, "Automatic Sorting System Using Machine vision," Multi Disciplinary International Symposium on Control, Automation & Robotics, vol. 1, 2010.

[19] C. K. Kunhimohammed, K. K. Muhammed Saifudeen, S. Sahna, M. S. Gokul and S. U. Abdulla, "Automatic Color Sorting Machine Using TCS230 Color Sensor And PIC Microcontroller," International Journal of Research and Innovations in Science and Technology, vol. 2, no. 2, pp. 2394-3866, 2015.

[20] K. Kumar and S. Kayalvizhi, "Real Time Industrial Colour Shape And Size Detection System Using Single Board," International Journal of Science, Engineering and Technology Research (IJSETR), vol. 4, no. 3, pp. 529-533, 2015.

[21] J. Sobota, R. PiŜl, P. Balda and M. Schlegel, "Raspberry Pi and Arduino boards in control education," IFAC Proceedings Volumes, vol. 46, no. 17, pp. 7-12, 2013.

[22] S. Silva, D. Duarte, R. Barradas, S. Soares, A. Valente and M. Reis, ARDUINO RECURSIVE BACKTRACKING IMPLEMENTATION, FOR A ROBOTIC CONTEST, 2017, pp. 169-178.

[23] M. A. Abdelaziz and A. D. Salman, "Mobile Robot Monitoring System based on IoT," *Xi'an Jianzhu Keji Daxue Xuebao/Journal of Xi'an University of Architecture & Technology,* vol. 12, pp. 5438-5447, 2020.

[24] K. Nosirov, S. Begmatov, M. Arabboev, T. Kuchkorov, J. C. Chedjou, K. Kyamakya, P. D. Silva and K. Abhiram, "The greenhouse control based-vision and sensors," *14th International FLINS Conference (FLINS 2020),* pp. 1514-1523, 2020.

[25] A. M. Kottalil, B. B. Krishnan, A. Anto and B. Alex, "Automatic Sorting Machine," *Journal for Research,* vol. 2, no. 4, pp. 2395-7549, 2016.

[26] V. Chakole, P. Ilamkar, R. Gajbhiye and S. Nagrale, "ORANGES SORTING USING ARDUINO MICROCONTROLLER," *International Research Journal of Engineering and Technology (IRJET)* , vol. 6, no. 2, pp. 2395-0072, 2019.

[27] J. W. Woods, "Chapter 6 - Image Perception and Sensing," in *Multidimensional Signal, Image, and Video Processing and Coding (Second Edition)*, Academic Press, 2012, pp. 193-221.

[28] J. Chouinard, "The Fundamentals of Camera and Image Sensor Technology," [Online]. Available: https://www.visiononline.org/us erassets/aiauploads/file/cvp_the-fundamentals-of-camera-and-image-sensor-technology_jon-chouinard.pdf. [Accessed December 2020].

[29] P. Withagen, F. C. A. Groen and K. Schutte, "CCD Color Camera Characterization for Image Measurements," *IEEE Transactions on Instrumentation and Measurement,* vol. 56, pp. 199 - 203, 2007.

[30] X. Meng, "Digital Image Processing Technology Based on MATLAB," in *the 4th International Conference*, 2018.

[31] A. A. Yahya, "Teaching Digital Image Processing Topics via Matlab Technique," *International Journal of Information and Education Technology,* vol. 9, pp. 729-734, 2019.

[32] J. Velasco and A. D. Africa, "Development of a urine strip analyzer using artificial neural network using an android phone," *ARPN Journal of Engineering and Applied Sciences,* vol. 12, pp. 1706-1713, 2017.

[33] F. Garcia-Lamont, J. Cervantes, A. López and L. Rodriguez, "Segmentation of images by color features: A survey," *Neurocomputing,* vol. 292, pp. 1-27, 2018.

[34] H. D. Cheng*, X. H. Jiang, Y. Sun and J. Wang, "Color image segmentation: advances and prospects," *Pattern Recognition,* vol. 34, no. 12, pp. 2259-2281, 2001.

[35] G. Ramella and G. Sanniti di Baja, "A new technique for color

quantization based on histogram analysis and clustering," *International Journal of Pattern Recognition and Artificial Intelligence,* vol. 27, 2013.

[36] V. Chernov, J. Alander and V. Bochko, "Integer-based accurate conversion between RGB and HSV color spaces," *Computers & Electrical Engineering,* vol. 46, pp. 328-337, 2015.

[37] M. B. ABDALLAH, A. Sessi, M. Kallel and M. S. BOUHLEL, "Different Techniques of Hand Segmentation in the Real," *International Journal of Computer Applications & Information Technology,* vol. 2, no. 1, pp. 45-49, 2013.

[38] J. R. M. Sandoval, E. M. Sandoval, M. Martinez-Rosas and M. Miranda, "Color Analysis and Image Processing Applied in Agriculture," 2018, pp. 61-78.

[39] B. C. Ly, E. B. Dyer, J. L. Feig and A. L. Chien, "Research Techniques Made Simple: Cutaneous Colorimetry: A Reliable Technique for Objective Skin Color Measurement," *Journal of Investigative Dermatology,* vol. 140, pp. 3-12.e1, 2020.

[40] S. Karis, W. H. Bin Mohd Saad, N. Mohd Ali, K. C. We, N. R. A. Razif, N. Selamat, A. F. Zainal Abidin, M. Kasyfu and A. Ahmad, "Fruit sorting based on machine vision technique," vol. 8, no. 4, pp. 31-35, 2016.

[41] N. K. Delina, I. H. Ayub Wahab and A. Khairan, "The Measurement of Maturity Level in Chili's Using Index Pixel," *Journal of Physics: Conference Series,* vol. 1569, no. 2, 2020.

[42] J. McCarthy, "WHAT IS ARTIFICIAL INTELLIGENCE?," 2004. [Online]. Available: http://jmc.stanford.edu/articles/whatisai.html. [Accessed December 2020].

[43] T. Gevorgyan, "Adoption and inclusion of Artificial Intelligence in digitalization strategies of organizations," 2019.

[44] M. Jordan and T. M. Mitchell, "Machine Learning: Trends, Perspectives, and Prospects," *Science (New York, N. Y.),* vol. 349, pp. 60-255, 2015.

[45] A. Moubayed, M. Injadat, A. B. Nassif, H. Lutfiyya and A. Shami, "E-Learning: Challenges and Research Opportunities Using Machine Learning & Data Analytics," *IEEE Access,* vol. PP, p. 1, 2018.

[46] "Use of Decision Trees and Random Forest in Machine Learning An Insight into Supervised Learning for Classification Problems," TechVidvan, [Online]. Available: https://techvidvan.com/tutorials/supervised-learning/. [Accessed 7 November 2020].

[47] S. Luthra, "MACHINE LEARNING : AN AUTOMATED LEARNING APPROACH," *International Journal of Computer Engineering and Applications,* vol. 12, pp. 156-161, 2018.

[48] A. Mehta, "Machine Learning," digitalvidya, [Online]. Available: https://www.digitalvidya.com/blog/supervised-learning/. [Accessed 7 November 2020].

[49] "Power Window Motor (Wira) - Left," cytron, [Online]. Available: https://my.cytron.io/p-power-window-motor-wira-left. [Accessed 11 November 2020].

[50] "10Amp 5V-30V DC Motor Driver," cytron, [Online]. Available: https://my.cytron.io/p-10amp-5v-30v-dc-motor-driver?r=1&gclid=EAIaIQobCh MIpdTylcWd7gIVCYNLBR2Tt gB_EAQYAiABEgJ36vD_BwE. [Accessed 11 November 2020].

[51] "ARDUINO UNO REV3," Arduino Store, [Online]. Available: https://store.arduino.cc/usa/ardui no-uno-rev3. [Accessed 20 December 2020].

[52] "Controlling MD10C with Arduino," Cytron Technologies, [Online]. Available: https://tutorial.cytron.io/2013/07 /29/controlling-md10c-with-arduino/. [Accessed 20 November 2020].

[53] "12V 28BYJ-48 Stepper Motor + ULN2003 Driver Board," cytron, [Online]. Available: https://my.cytron.io/p-12v-28byj-48-stepper-motor-plus-uln2003-driver-board?r=1&gclid=EAIaIQobCh MIq5OnjtCd7gIVCx4rCh3DQA M3EAQYAyABEgKR5PD_Bw E. [Accessed 12 November 2020].

[54] "Control 28BYJ-48 Stepper Motor with ULN2003 Driver & Arduino," lastminuteengineers, [Online]. Available: https://lastminuteengineers.com/ 28byj48-stepper-motor-arduino-tutorial/. [Accessed 20 December 2020].

[55] "OV7670 VGA Camera Module," cytron, [Online]. Available: https://my.cytron.io/p-ov7670-vga-camera-module?r=1&gclid=EAIaIQobC hMIsNmo0MWd7gIVyH4rCh2v ewohEAQYAyABEgLijfD_Bw E. [Accessed 12 November 2020].

[56] R. Pelayo, "Arduino Camera (OV7670) Tutorial," teachmemicro, [Online]. Available: https://www.teachmemicro.com/ arduino-camera-ov7670-tutorial/. [Accessed 21 November 2020].

[57] "Texture Analysis Using the Gray-Level Co-Occurrence Matrix (GLCM)," mathworks,

[Online]. Available: https://www.mathworks.com/help/images/texture-analysis-using-the-gray-level-co-occurrence-matrix-glcm.html. [Accessed 15 November 2020].

[58] "regionprops," mathworks, [Online]. Available: https://www.mathworks.com/help/images/ref/regionprops.html. [Accessed 15 November 2020].

[59] "Neural Networks," mathworks, [Online]. Available: https://www.mathworks.com/discovery/neural-network.html. [Accessed 17 November 2020].

[60] "Chapter 1 Introduction and Role of Artificial Neural Networks," in *Principles of Artificial Neural Networks*, World Scientific Pulishing Co. Ptc. Ltd, 2013, pp. 1-112.

[61] H. N. K. Al-Behadili, "Classification Algorithms for Determining Handwritten Digit," *Iraqi Journal for Electrical And Electronic Engineering,* vol. 12, pp. 96-102, 2016.

[62] T. Le, M. Y. Lee, J. Park and S. W. Baik, "Oversampling Techniques for Bankruptcy Prediction:Novel Features from a Transaction Dataset," *Symmetry,* vol. 10, p. 79, 2018.