"DEVELOPMENT OF SMART SORTING MACHINE USING ARTIFICIAL INTELLIGENCE FOR CHILI FERTIGATION INDUSTRIES"

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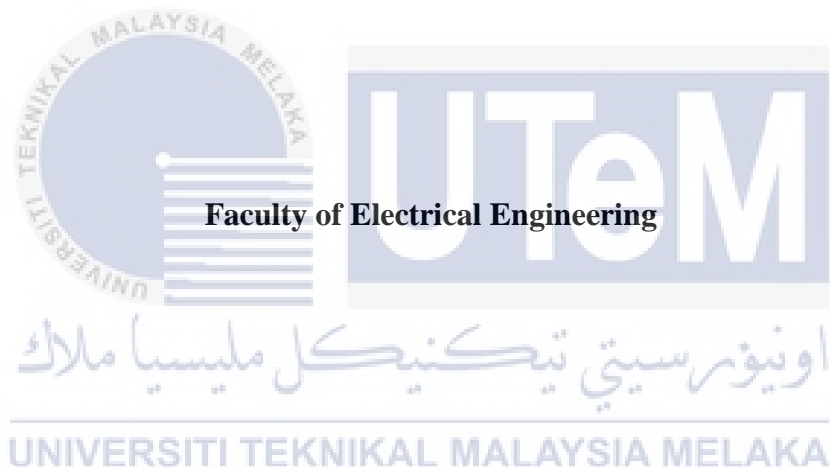
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A final year project report submitted
in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "DEVELOPMENT OF SMART SORTING MACHINE USING ARTIFICIAL INTELLIGENCE FOR CHILI FERTIGATION INDUSTRIES" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.
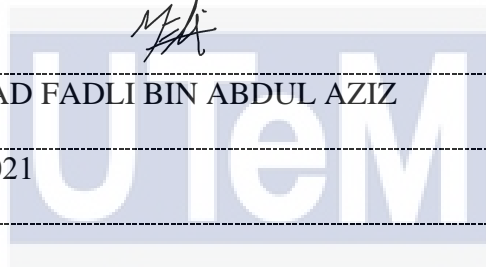
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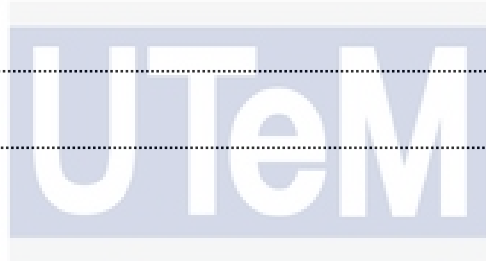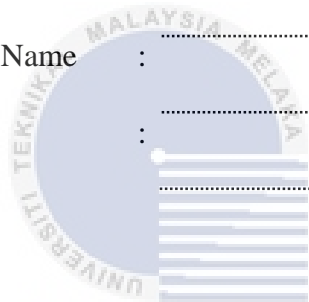
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APPROVAL

I hereby declare that I have checked this report entitled "title of the project" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature   :

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DEDICATIONS

I dedicate this to my beloved mother and father, for their kindness, devotion and endless

support.

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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 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.

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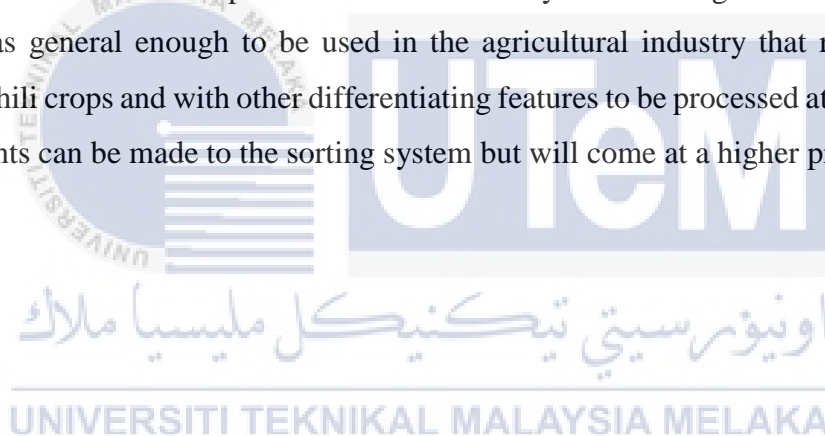
ABSTRAK

Proses automatik merupakan satu keperluan didalam industri pertanian terutamanya tanaman cili, yang menggunakan teknik pemprosesan gambar dan pengelasan tanaman cili selalunya berdasarkan warnanya, bentuknya dan teksturnya. Tujuan kajian ini adalah untuk mengbangunkan sebuah mesin pengasing mudah alih yang mampu untuk mengasingkan cili berdasarkan warnanya menggunakan *Artificial Neural Network (ANN)* dan untuk menganalisis prestasi menggunakan cara *plot confusion.* Sepuluh sampel gambar cili hijau dan sepuluh gambar cili merah dilatih menggunakan algoritma pengetahuan yang terdapat didalam program *MATLAB* yang mengandungi proses mengekstrak ciri khas dan diuji dengan membandingkan prestasi dengan set data yang lebih besar, iaitu empat puluh sampel gambar cili. Jaringan terlatih dari 20 sampel menghasilkan ketepatan keseluruhan 80 peratus dan ke atas, sementara rangkaian terlatih dari 40 sampel menghasilkan ketepatan keseluruhan 85 peratus. Hasil keputusan ini menunjukkan kepentingan kajian tambahan kerana reka bentuk mesin pengasing pintar ini adalah terlalu am bagi digunakan didalam industri pertanian yang memerlukan jumlah tanaman cili yang banyak dan mempunyai ciri-ciri khas yang berlainan untuk diproses pada masa yang sama. Penambahbaikan boleh dilakukan keatas sistem pengasingan tetapi akan datang pada harga yang lebih mahal.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	-	Ampere
V	-	Voltage
AC	-	Alternating Current
DC	-	Direct Current
Kgf.cm	-	Kilogram Force Centimeter
(m/s)	-	Metre per Second
mm	-	Millimeter
RPM	-	Revolution per Minute
T	-	Number of Sprocket Teeth
RGB	-	Red Green Blue Color Space
HSV	-	Hue Saturation Value Color Space
AI	-	Aritifial Intelligence
ANN	-	Artificial Neural Network
CCD	-	Charge-Couple Device
CMOS	-	Complementary Metal Oxide Semiconductor
GLCM	-	Gray Level Co-occurrence Matrix
MATLAB	-	Matrix Laboratory
PIC	-	Peripheral Interface Controller
PLC	-	Programmable Logic Controller
PWM	-	Pulse Width Modulation
ROI	-	Region of Interest
μ	-	Mean
σ	-	Standard Deviation
y_i	-	Classification Label
x_i	-	Input Vector
$f(\sum x)$	-	Sigmoid Function
w	-	weight
t_i	-	Target Vector
ROC	-	Receiver Operating Characteristic

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CHAPTER 1 CHAPTER 1

INTRODUCTION

1.1   Motivation

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.

1.2   Problem Statement

Chili can be sorted by distinguishable features such as the color and shape of the crops. This operation for sorting chili crops can be done by using human workforces in agricultural industries. However, this task will be time-consuming and costly if the segregation process is to be done manually as humans will take time for the chili classification. Thus the speed of the conveyor that moves the crops to be sorted depends on the number of workers that operate this task. Besides that, it is also hard to determine the accuracy of the manual classification.

Therefore, a study for the classification will help to sort the chili accurately and faster. Artificial intelligence (AI) has been chosen for this classification problem. The focus of this study is to devise a sorting system mechanism by using the AI technique for chili crops based on their color. The performance of the system will be evaluated by using plot confusion and plot receiver operating characteristic curve (ROC) to confirm the result.

1.3   Objective

The objectives of the study are as follows:

a) To design and develop a portable chili sorting machine.

b) To extract color from the images of chili crops and to classify chili using Artificial Neural Network (ANN).

c) To perform performance evaluation using the Plot Confusion technique.

1.4   Scope of the Study

This project mainly focuses on:

a) The sorting machine will be portable.

b) Classification of red and green chilies.

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c) The training process of the artificial neural network uses 10 image samples for each color of the chili and is compared with the performance of 20 image samples for each color of the chili.

d) The performance of the classifier will be tested using plot ROC and plot confusion.

1.5 Significance of the Study

Data analysis and classification of two or more different classes is a crucial skill for working in the industrial sector at this age of technological advancement. As the automation of processes and operations becomes more common in many major industries, the need to possess appropriate skills and training especially in artificial intelligence (AI) is a must. In this project, the classification of chilies based on their colors can be achieved by using Artificial Neural Network (ANN) which is a subtopic of AI and it is a fundamental approach in the data learning network. Furthermore, ANN is easier to be implemented while also able to perform better than any other classical statistical approach.

To prove the effectiveness of the method, performance evaluation must be conducted. By using the Plot confusion technique, the performance of ANN that classified the chili can be rated. The purpose of the performance evaluation is to evaluate the accuracy, precision, specificity, and sensitivity of the data.

For this study, Artificial Neural Network (ANN) classifier is the major focus for the classification of chili. This is because ANN is becoming a trend in recent years in various fields of study and can be analyzed from the fact that ANN-related fields of studies published in the Scopus platform increased yearly. This proves that the study of chili classification by using ANN will be a beneficial move. Figure 1.1 shows the increasing graph of documents published in Scopus from the year 2000 to 2020 for ANN studies increasing dramatically.
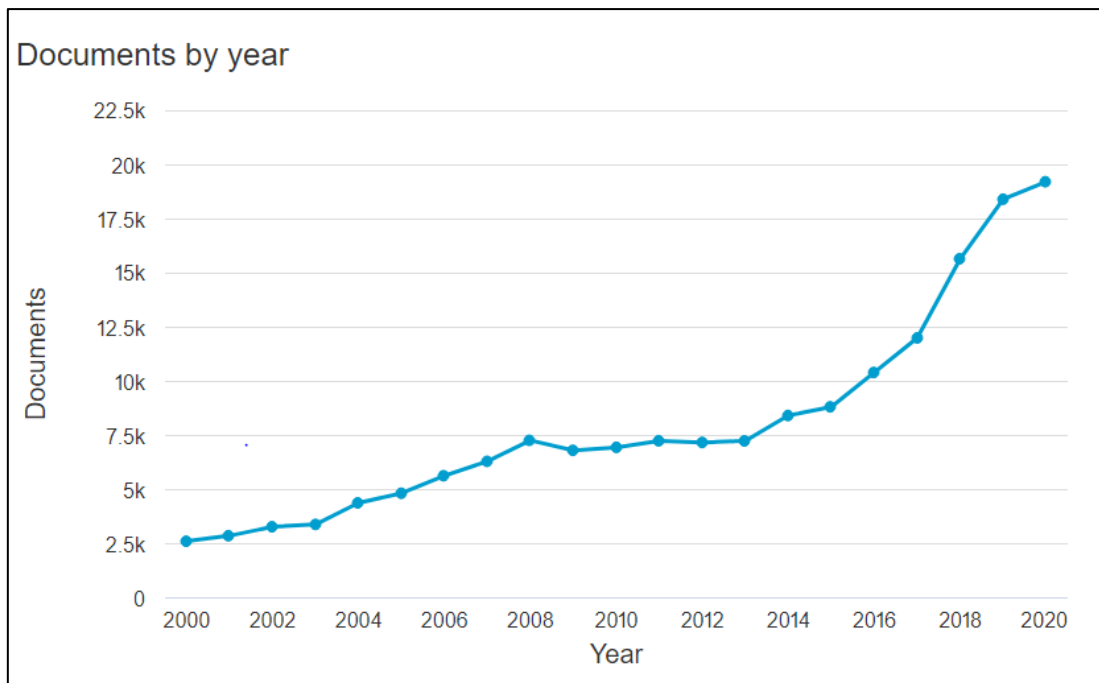
Figure 1.1: Documents Published in Scopus Platform for ANN Studies [14]

1.6   Project Outline

In the next following chapter, the report is organized as follows:

Chapter 2: Provides the overview of past studies and concepts for designing a portable sorting machine based on the suitable criteria which are the object to be sorted, chili, the required and relevant sorting mechanism as well as the options for controlling the sorting machine.

Chapter 3: Provides the details of the chosen method based on the previously studied variety of options from chapter 2. The details are arranged in a way to represent the process of designing, planning, choosing the correct hardware and electrical equipment. This is a crucial process that determines the smoothness of progress when developing the smart sorting machine. Lastly, the methodology for designing the programming will be elaborated.

Chapter 4: Present the outcome from feature extraction data analysis. The performance results from the trained network are then compared between the performance of the classifier when using only 20 samples of chili images with the network performance when using 40 samples of chili images.

Chapter 5: The conclusion from the performance comparison of the trained network. A larger dataset to be fed into the model network proved to be more accurate than when using a smaller dataset which is 20 samples only. Further improvements are also discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1   Chili Sorting System

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.

2.1.1   Chili

Chili is one of the most common ingredients for dishes around the world. Chili previously and normally was sold in the traditional market before the emerging of supermarkets that contributes to the rapid demand for the product. Chili can be classified into several varieties such as bird's eye, cayenne, habanero, poblano, and jalapeno peppers with different sizes, shapes, and also colors. This type of vegetable is known around the world as it is one of the most important ingredients in a variety of cuisines [15].

2.1.2   Sorting Mechanism

To design a sorting machine system, one must consider the mechanism to detect the position of the object to be sorted as well as the capability of the system to sort the object according to the movement speed of the object. A previous study designed a strategy to sort objects at high speed by using a Delta robot [16]. 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.

From a previous study, the designer makes use of ARDUINO Uno to control a servo motor which starts a V-shaped vibrating conveyor to load one chili at a time for the loading process. A belt conveyor then transported the chili to the sorting system which was processed by

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using a CCD Camera (Charge-couple device) [17]. By using this sorting system, only one chili can be processed at one time. A vibrating tray mechanism was also used for the rice grains sorting machine to remove defective grains from the rest of the products [18]. The grains dropped from the vibrating tray into a chute with several channels before analyzed by a camera sensor module. An ejector with a pneumatic sorting system then continued to blow the defective grains into a segregated container. Although this study was made specifically for granular objects, the mechanism can be applied for chili processing but with one weakness such that the system only separates unwanted products from the rest without any other differentiating features.

A system with multiple features to differentiate will be a bit complex. In another research, a system was 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 [19]. The important feature that this study was missing was the color trait for the product.

2.1.3 Control System

There are various methods for controlling a sorting machine system. 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). This project will be using a system that can control several devices such as a vision module for detection purposes, motors to drive the system, and also the power module system to segregate chili based on their color.

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 [20], [21], [22]. For automation of sorting system, ARDUINO controller has been used in different research to control three conveyor system that consists of dc motor, stepper motor and servo motor [23]. Another study suggested that a sorting system based on color by using the ARDUINO microcontroller will prove high efficiency with low cost [24].

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An automatic sorting system that applied machine vision can also be accomplished by using a PIC microcontroller [25]. The system makes use of a proximity sensor, two servo motors, and also a stepper motor that was controlled by the PIC microcontroller. For the vision module and sensing, MATLAB programming was used for the image processing technique. Both MATLAB and PIC microcontrollers will then control the system by using an interface. Another type of system developed by using PIC microcontroller shows that it was able to control several DC motors embedded into the conveyor system and also TCS230 for color sensing circuit [26]. The researchers however suggested that the system has to be replaced with the PLC microcontroller for more efficiency and practicality at the expense of higher cost.

For Raspberry Pi, a study used the microcontroller to detect color, shape, and size but with the implementation of the OpenCV program to enable the system to operate in real-time application [27]. This study proved that the overall cost can be reduced when the system ran by a single-board configuration. However, regardless of the choices between the ARDUINO board and Raspberry Pi, both have been described as easy to use and also inexpensive [28].

2.2   Image Processing Technique

This is an important process that can help the feature extraction process to perform the task better.

2.2.1   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 [29]. 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 [30]. The article also provided the criteria for selecting the suitable camera type based on the usage which are 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 [31].

2.2.2 Digital Image Processing

Digital image processing has many techniques that can be applied based on the requirement such as by using image editing, anisotropic diffusion, neural networks, pixelation, and partial differential equation method [32].

With the advent of new technologies, a more accurate, precise, and faster sorting time can be achieved. Computer vision method for grading and sorting food products can be used for various types of food such as bakery products, fruits, grain,s and vegetables including chili by utilizing image processing techniques [33]. Another method of sorting chili is by using machine vision software by determining the level of ripeness for harvesting purposes. Open CV software in the Phyton environment was used for the segregation process to classify different kinds of materials such as cardboard, aluminum, and pumice stone in a random order [34].

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 [35]. 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 [36].

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 2.1 shows the block diagram of a digital image process system.