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A Non-Destructive Oil Palm Fruit Freshness Prediction System with Artificial Neural Network

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Abstract: The economical, rapid, and non-destructive method using reflectance Near-Infrared Spectroscopy (NIRS) technique were designed and developed for oil palm fruit (Elaeis Guineensis) freshness prediction. The ripe maturity oil palm freshness of Tenera variety was used for this study by two consecutive days. The measurement of spectral value was obtained with a linear array sensor. The Artificial Neural Network (ANN) was trained with Levenberg-Marquardt algorithm by using half of the data sets, and then the rest of data was separated equally but randomly for both validation and test analysis. The performance of the oil palm fruit freshness prediction system was evaluated. Results indicate that the ANN with 6 hidden neurons achieved the best prediction accuracy with root mean squared error (RMSE) and the correlation coefficient (R) of 6.8449 hours and 0.8418, respectively. This suggests that the proposed method is promising to be further developed to automate oil palm freshness inspection.

Keywords: Oil Palm Fruit, Freshness Prediction, Near Infrared, Artificial Neural Network

1. Introduction

Palm oil is the most traded oil in the world. In 2015, palm oil is exported from Malaysia are reached 17.45 million tons. Harvesters spend their days stare at the plantation to determine the maturity of the oil palm fruit across 5.64 million hectares of Malaysia palm plantations at 2015 [1]. The maturity of oil palm fresh fruit judgement is made by harvesters using the visual inspection during harvest and even the fruit freshness inspection at mill side. Oil yield would be reduced when the fruit bunch was harvested too early. On the other hand, the oil quality would be lower for overripe fruits with high Free Fatty Acid (FFA). The greatest oil quality can only be obtained from the ripe fruit that was harvested at its optimal time.

The ripeness and freshness are the two of the most important conditions for assessment for oil palm extraction rate according to Mr Chow Voon Yang, Scientist, from Sime Darby Technology Centre Sdn. Bhd. In fact, both ripeness and freshness play crucial roles in the industry to fulfil the expectation of consumers and customers. The oil extraction rate (OER) is the rate of the oil quantity that can be extracted from the harvested fruits. According to the Malaysian Palm Oil Board (MPOB), Palm Oil Engineering Bulletin No 103, Malaysia aims to increase the OER of oil palm from 20.45% (2010) to 23% (2020). Quality control could be one of important initiatives to improve OER in the near future. This is because the OER is affected by ripeness and freshness [2]. Freshness of the Fresh Fruit Bunch (FFB) will be

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degraded if the time taken of the harvested to mill is longer [3], [4]. For instance, FBB collection station will only transfer the collected FFB to mill when the amount of FFB had reach certain amount of quantity. Obviously, the time taken for the harvested FFB sent to the mill is extended along the process and the freshness is affected. Thus, there is a need to grade the freshness of the FFB when the FFB reached the mill.

The oil palm FFB grading method had been reached using different technology such as capacitive sensor [5], fluorescence technique [6], and machine vision [7]. On the other hand, near infrared spectroscopic (NIRS) technology is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum between 400 and 2500 nm to relate to the component of interest. In fact, NIRS technology has been widely investigated to grade the internal qualities of different crops e.g. apples [8], peach fruit [9], avocado fruit [10], and pineapple [11]. This could be due to the fact that NIRS technology is non-destructive and rapid secondary measurement approach. However, the financial barrier of a commercial available NIRS is high. Adapting our recent proposed NIRS that consists of few basic components appears to be alternative to reveal the potential of NIRS in oil palm application [12]. Thus, the goal of this study was to investigate the feasibility of the proposed NIRS system that coupled with artificial neural network in predicting oil palm freshness.

2. Methodology

2.1 Hardware Development

Fig. 1 illustrates the design of the sensing device used for this study with reflectance method. The light is transmitted to the oil palm fresh fruit at the compartment two and reflected the grating. The grating will disperse the light to a linear array sensor that located at the last compartment. The sensor connected to the Arduino Leonardo board as a controller for the peripherals manage purpose at the bottom level. The grating and the sensor will be inside the black sensor box. This reduces the light reflection in the sensor box.

The Quartz-Tungsten-Halogen Lamp (QTHL) from Thorlabs selected as the light source for NIRS because of its specification with broadband emission (400 – 2200 nm). The collimator lens used to focus the light rays from the halogen lamp to one direction and parallel.

The reflected light emits to the grating pass through a slit. The slit used to ensure the light straight to the grating. The NIR Transmission Gratings with 24.8˚ Groove Angles from Thorlabs used for splits and diffracts light into several beams traveling in different directions as well as to ensure the dispersed light from the various wavelength can reach the sensor. The linear array sensor used to detect the light intensity with 256 x 1-pixel array. The prototype of the sensing device will be cover up with a black box as shown in Fig. 1. This black box to ensure the surrounding light will not go into the devices.

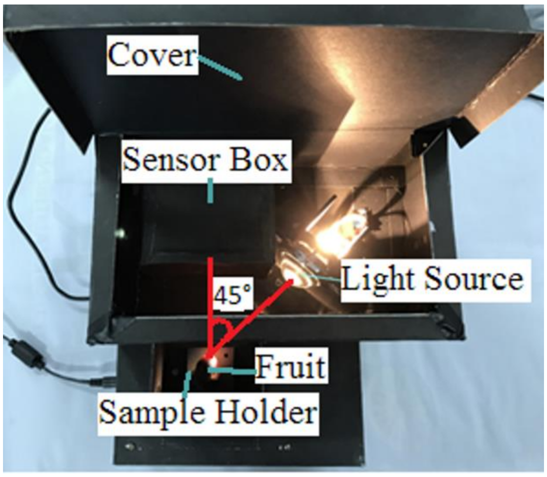

Fig. 1 – Prototype of the sensing device

2.2 Data Acquisition

A total of 20 oil palm fruits were collected from Pertubuhan Peladang Kawasan (PPK). This 20 samples collected from two different bunches. Fig. 2 illustrates five fruits from the top of each bunches and another five fruits from the bottom of each bunches so total samples are 20 fruits.

The spectrum of the sample present as 256 pixels of the sensor. The total duration for these 20 samples were 2 days, and 20 data were recorded for every 6 hours. This is because the FFA content will become unacceptable level by 72 hours after harvesting [13]. The total spectrum of the samples were 160 data.

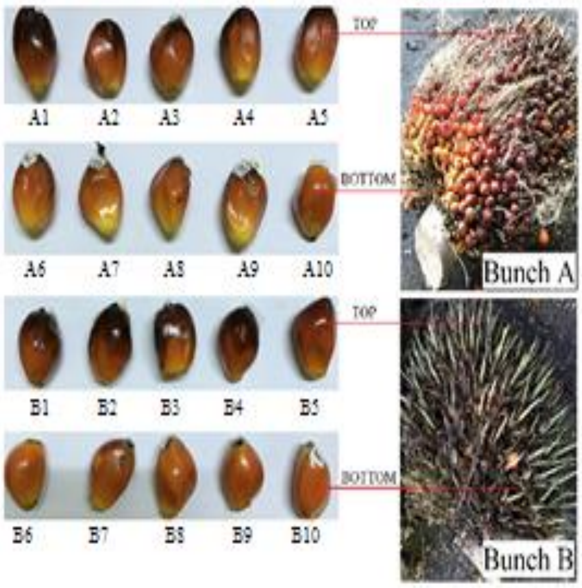

Fig. 2 – The collected samples from the top and bottom part of bunches

2.3 Modelling of Neural Network

The Neural Network Fitting toolbox from Matlab software (R2017b) was used to model the acquired data. The spectrum of the data is the input of the model. The output of the model is the predicted freshness of the oil palm fruit. The samples were trained to start from 1 until 10 hidden neurons. The samples divided randomly into training (50% = 80data), validation (25% = 40data), and testing (25% = 40data). The performance of the neural network evaluated with referred to the root mean squared error (RMSE) and the correlation coefficient (R). The lower RMSE value is better and the best result is zero, meaning no error. The R means a close relationship with value 1 and 0 is a random relationship.

3. Results and Discussion

The sensor completely covered by the box and the sensor box sealed with the black material on the surface. This reduces the light reflection in the sensor box. This measurement handling criterion is very important and crucial where the exposure of light can influence the accuracy of reading and reliable of measurement. There is no light exposure when the box covered. The spectrum for all the samples as shown in Fig. 3. The intensity of the near infrared light resulted according the internal quality of the oil palm fresh fruit. All of the spectrums used for training, validating, and testing the Neural Network.

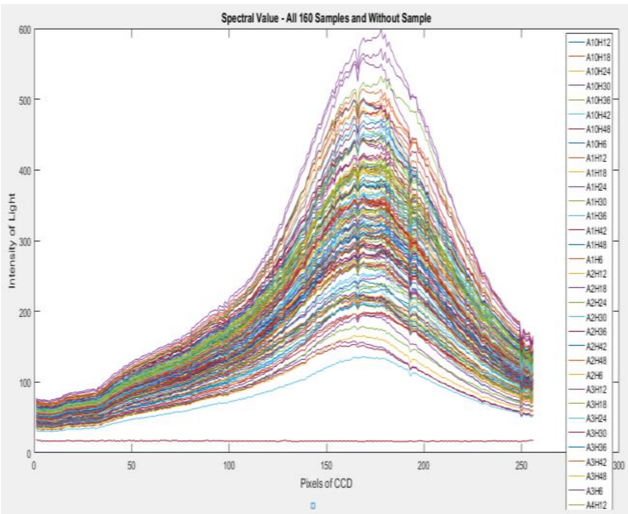

Fig. 3 – The result of no light exposure and the spectra of all samples

The optimal hidden neuron was investigated from one to 10 hidden neurons, and Levenberg-Marquardt was used as the learning algorithm. The ANN model was trained for 20 times for each hidden neuron and the lowest root mean squared error (RMSE) and correlation coefficient close to 1 is selected. The selected result will be show in Fig. 4. The lowest RMSE was found when the hidden neuron was set to 6 with RMSE of 6.8449 hours.

Fig. 5 illustrates the relationship between the predicted result and the actual result. The correlation for the training, validation and testing are 0.9758, 0.8701, and 0.8418, respectively. The closer the correlation to the 1, the result is better. The graph of the training, validation, and testing have also the trend. The trend shows that the freshness of the oil palm fruit can be predicted.

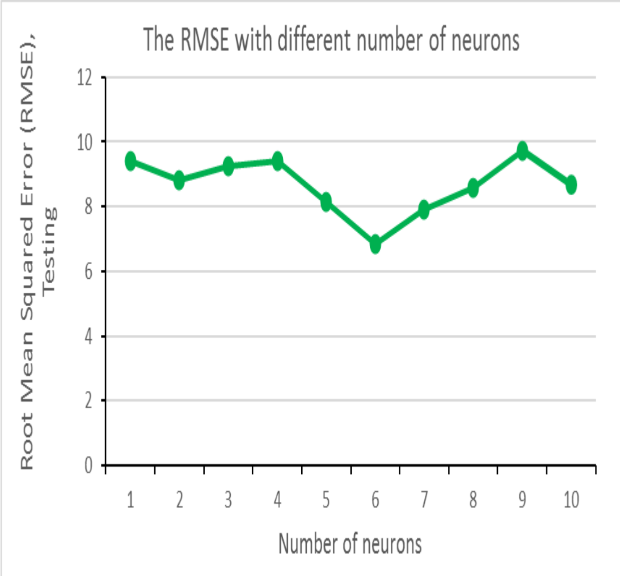

Fig. 4 - The root mean squared error for testing with different number of hidden neurons.

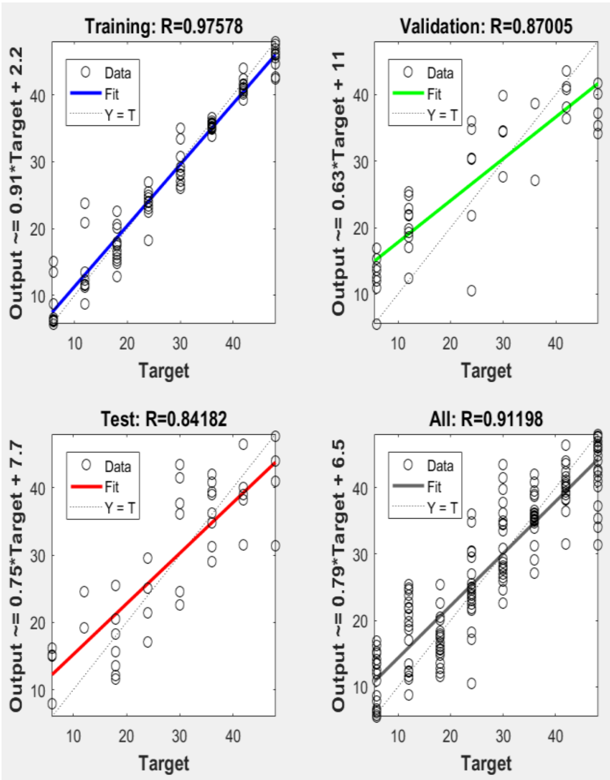

Fig. 5 - The calibration, validation, and the prediction performance of ANN with six hidden neurons.

(1)

4. Conclusion

Finding shows that the designed near-infrared spectroscopy system coupled with Artificial Neural Network (ANN) is promising to non-destructively classify the palm fruit freshness with a satisfied predictive performance. ANN with six hidden neurons achieved the lowest root mean square error of 6.8449 hours with a correlation coefficient of 0.8418. This suggests that the proposed system is promising to be further developed in predicting other types of internal quality such as free fatty acid for palm oil non-invasively.

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