Evolution in Electrical and Electronic Engineering Vol. 4 No. 2 (2023) 574-581

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Palm Fresh Fruit Bunches (FFBs) Colour Grading System Using Raspberry Pi

Nadzir Mohd Zamri [1], Abul Khair Anuar [1]*

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2023.04.02.070
Received 28 June 2023; Accepted 07 September 2023; Available online 30 October 2023

Abstract: This study presents a Colour Grading System Using Raspberry Pi. In this study, data collection was obtained from the ROBOFLOW database and it comes with three different categories ripe, unripe and overripe. The dataset needed to sort manually to fill the requirement for image training progress using transfer learning in MATLAB. The method uses Convolutional Neural Networks with untrained ResNet-50 architecture for deep learning layers and runs in MATLAB with the additional toolbox extension. Transfer Learning is a method to design a neural network by uploading the dataset of training and validating FFBs images. Hardware and software configurations were made to perform colour grading of FFBs using ResNet-50 and Raspberry Pi. The colour grading system results show that FFBs' grades can be determined using MATLAB and Raspberry Pi hardware. The training progress of image validation achieves more than 90% accuracy and the average of final image validation is 96.71% from 10 times of training progress. After the image validation, real-time classification is done at KOPDAP Batu Pahat to determine the system's accuracy. Classification results were recorded and calculated using the confusion matrix method. The results show the accuracy for the ripe class is 70%, unripe is 83% which is the highest and the lowest accuracy is overripe, which only achieves 60%.

Keywords: FFBs, ResNet-50, CNN, Raspberry Pi

1. Introduction

In 2020, the world's palm oil production made up 25.8% of and 34.38% of exportation. Malaysia contributed 9.1% and 19.7%, respectively, of the world's total oil and fat production and exports in the same year, considering all domestically produced oils and fats [1]. Crude palm oil refinery started in the early 1970s in response to the government's goal for further industrialization. A wide variety of processed palm oil products were introduced at the same time as refineries were being developed [1].

Palm Fresh Fruit Bunches (FFBs) are the raw material for palm oil mills. The oil palm tree (Elaeis guineensis) originated from West Africa and was cultivated as an agricultural crop in Malaysia. A

**Corresponding author: abul@uthm.edu.my*

typical FFB weighs between 20 and 25 kilogrammes and contains 1,000 to 3,000 fruitlets of the palm fruit, also known as the fruitlet, is virtually spherical or elongated in shape [1].

According to Malaysia Palm Oil Board (MPOB), a bunch is considered as ripe if there are at least ten empty sockets with 50% fruits still attached to the bunch and it has a yellowish and reddish outer layer and yellow-coloured-coloured mesocarp. In contrast, the colour of an unripe bunch is black and purple black on the outer layer with yellow mesocarp without any detached fruit from the bunch's socket. Lastly, an overripe bunch has darkish red outer colour and has more than 50% of detached fruit but still has at least 10% fruit attached to the bunch [2]. The fruit from the tree is processed and produces two main products, which are crude palm oil and palm kernel [3].

The quality of palm oil is determined based on its texture, shape, and colour features. Different ripeness of palm fruit holds different qualities and uses. The ripeness of the palm fruit can be determined by the colour of the fruit and the attached fruits on the bunch socket [4].

2. Literature Review

2.1 Fresh Fruit Bunches

According to Corney et al., oil palm trees produce both male and female flowers on the same plant, making it a monoecious plant. The palm produces 10 to 25 kg bunches that are nearly spherical or elongated and contain 1,000 to 3,000 fruits. Unripe fruit is typically dark purple, almost black, while mature fruit is orange red. The fruit consists of a soft mesocarp surrounding a hard kernel (seed) enclosed by an endocarp. Before being replanted, the oil palm may reach a height of 10 metres after 25–30 years. One-fourth of the harvested FFB is oil, one-fourth is seeds (5 percent kernels), one-fourth is mesocarp fibre, one-fourth is the shell, and one-fourth is empty fruit bunches [24]. Tenera, a hybrid between dura and pisifera, is the most extensively planted variety of oil palm in Malaysia. Per acre, Tenera yields 1 t of kernels and 4 to 5 t of crude palm oil (CPO) annually. Oil palm is the most productive oil crop in the world, requiring only 0.26 ha of land to produce 1 t of oil, compared to 2.22 ha for soybeans, 2.01 ha for sunflowers, and 1.52 ha for rapeseed [5].

The palm oil supply chain begins with oil palm nurseries. The economic objectives of the nursery phase are to decrease the period of immaturity in the field, give the best possible early output, and keep nursery expenses as low as possible. The palm trees in the nursery are grown in polybags. In the pre-nursery, germinated seeds are planted in small polybags (15 cm 23 cm, or 6" 9") until the seedlings are around three to four months old. They are then transplanted into big polybags (38 cm x 45 cm, or 15" x 18") and grown without protection until they reach between 12 and 15 months old. The distance between polybags in the primary nursery is 0.9 m x 0.9 m x 0.9 m, or 0.75 m x 0.75 m x 0.75 m, measured centre to centre. The soil in the prenursery and main nursery is watered daily with 0.5 and 1.5 to 2.5 litres of water, respectively. Typically, watering occurs twice daily [6].

2.2 Digital Image Processing

Digital image processing involves the manipulation of images using digital computers. In the preceding decades, its utilization has skyrocketed. It has numerous applications, ranging from remote sensing and geological processing to entertainment and medicine. Digital image processing is a fundamental element of multimedia systems, one of the pillars of the modern information society [7].

Digital image processing is a vast field that encompasses both general image processing methods and digital signal processing-specific methods. Consider a function f (x, y) of two continuous variables x and y as a picture. To handle it digitally, it must be sampled and transformed into a matrix of numbers. Quantization is essential to represent numbers digitally due to the limited precision of computers. These numbers with low precision are adjusted throughout the processing of digital images. Image enhancement, image restoration, image analysis, and image compression are some of the subcategories of digital image processing. In image enhancement, an image is often transformed using heuristic approaches so that a viewer can interpret it [7].

2.3 Deep Learning Neural Network

Artificial Neural Networks (ANN) match input patterns to desired outputs. It has numerous uses, including data categorization, data prediction, and data visualisation. ANN does not need predefined rules because it can learn and generalise from 'experience' or a series of given examples. In agriculture, ANN has been used to identify the ripeness, bruising, or shape of agricultural products [7].

Convolutional Neural Network (CNN) is a class of neural networks, referred to as CNN or ConvNet, is used for processing data with a grid-like topology, such as an image. An image, which is a binary representation of visual data, is composed of a series of pixels arranged in a grid-like manner, where pixel values are used to indicate the brightness and colour of each pixel [8].

A considerable amount of information is processed by the human brain the moment an image is observed. The entire visual field is covered by neurons, each functioning within its receptive field and connected to other neurons. Similarly, data processing in a CNN occurs within the receptive field of each neuron, just as in the biological vision system where neurons respond to stimuli within their restricted region called the receptive field. The arrangement of layers in a CNN is designed to detect simpler patterns initially (such as lines and curves) and progressively identify more complex patterns (including faces and objects). The utilization of a CNN allows computers to gain visual capabilities [9].

2.4 Residual Network-50 (ResNet-50)

ResNet-50 is a convolutional neural network that is 50 layers deep. ResNet, short for Residual Networks, is a classic neural network used as a backbone for many computer vision tasks. The fundamental breakthrough with ResNet was that it allowed us to train extremely deep neural networks with 150+ layers [10].

Convolutional Neural Networks have a major disadvantage 'Vanishing Gradient Problem'. During backpropagation, the value of the gradient decreases significantly, thus hardly any change comes to weights. To overcome this, ResNet is used. The ResNet 50 architecture is comprised of numerous components in which the correspond Resnet-50 convolution layer can be referred in [10]. It begins with a convolutional layer that employs a kernel size of 7 x 7 and 64 distinct kernels, each with a stride size of 2, yielding a single layer. This is followed by a maximum pooling layer with the same stride size of 2. The succeeding convolutional layer consists of a 1 x 1, 64 kernel, a 3 x 3, 64 kernel, and a 1 x 1, 256 kernel. In this stage, these three layers are repeated three times, resulting in a total of nine layers. This sequence is repeated four times, yielding a total of 12 layers. In addition, a 1 x 1, 256 kernel is utilised, as well as two more kernels of sizes 3 x 3, 256 and 1 x 1, 1024, which are repeated six times for a total of 18 layers. In addition, a 1 x 1, 512 kernel and two extra kernels of sizes 3 x 3, 512 and 1 x 1, 2048 are applied. This process is done three times, resulting in a total of nine layers. After this, an average pooling operation is conducted, followed by a 1000-node fully linked layer and a SoftMax function, resulting in a single layer. It is vital to remember that the activation functions and max/average pooling layers are not included in the layer count. Therefore, the ResNet 50 architecture consists of 50 layers in the deep convolutional network (1 + 9 + 12 + 18 + 9 + 1) [9].

3. Method

3.1 System design of FFBs classification system

Figure 1 shows the system design workflow. First, the system will be developed in MATLAB 2021b using the deep learning toolbox, ResNet50 untrained network architecture reused for implementing the convolutional layer in for the deep learning. Then, the Image data set that contains two folders contains 3 classes of FFBs ripeness to train and test the images using the Convolutional neural network.

This process is called Transfer Learning in MATLAB. Once the training and test process is done the data will be deployed into the Raspberry Pi hardware and camera modules will show the video and the percentage of the ripeness will appear as the output. After that, fruit bunches will be classified into 3 groups which are Unripe, Ripe and Overripe.

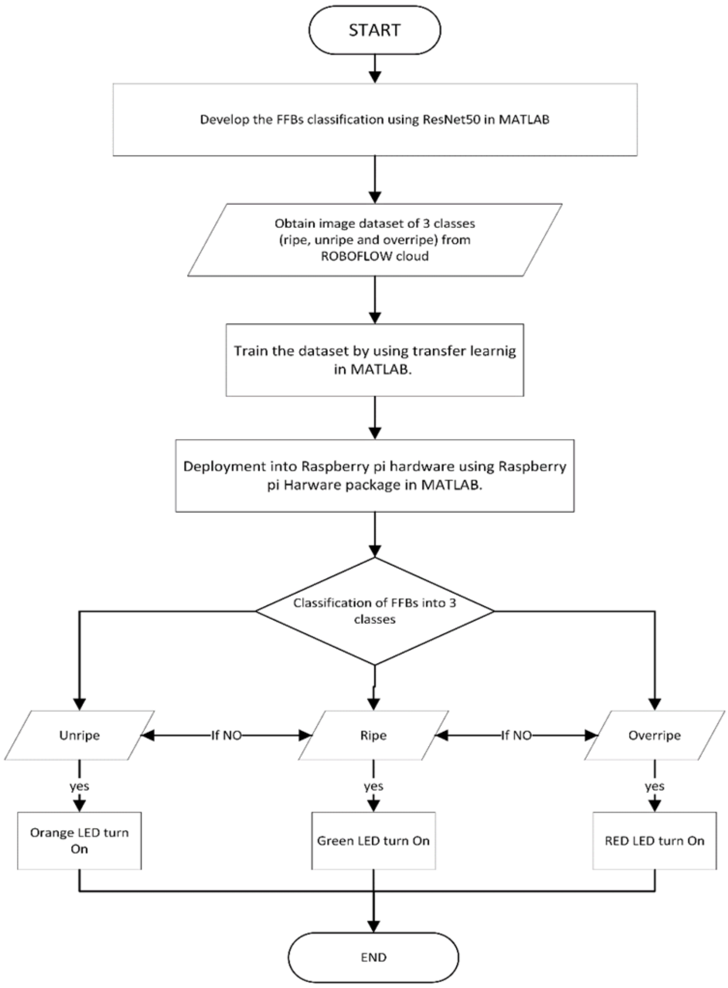

Figure 1: Flow of FFBs classification system

3.2 Images dataset and dataset manual classification

Palm FFBs images are crucial in the colour grading system because images need to go through image processing, training, and validation stages. In this work, the image dataset obtains from the ROBOFLOW cloud. The dataset named DataSawit contains 841 images file. Then, the images file was split into 2 files (train and test) and each file was manually divided into 3 categories (Ripe, Unripe and Overripe). Process of dataset classification is show in Figure 2. Table 1 shows the number of image training file contains 738 FFBs images, while the test file only contains 103 FFB images.

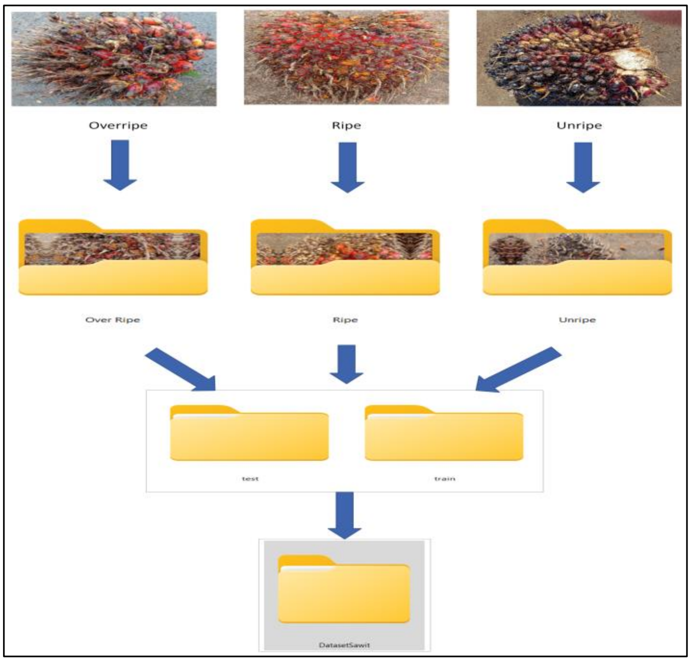

Figure 2: Images dataset and dataset manual classification

Table 1: Dataset images separation

Train image	Test image	Total
738	103	841

Figure 3 describes the sample pictures of FFBs classes inside the file that are already sorted in Figure 2.

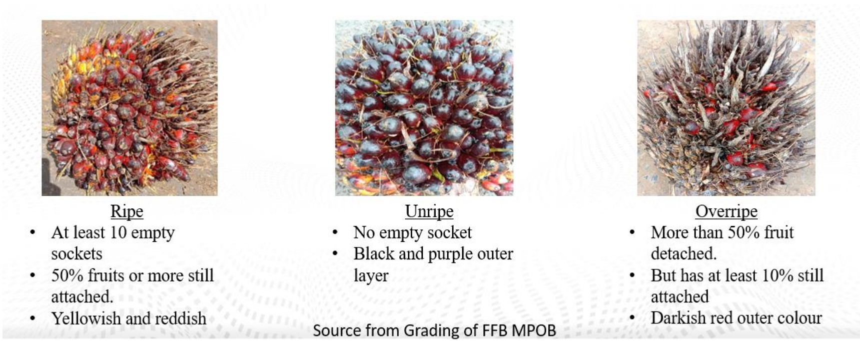

Figure 3: FFBs ripeness class

4. Results and Discussion

4.1 Image validation of FFBs

Figure 4 and Figure 5 are the output of the image training progress that was run inside MATLAB. Image training was repeated 10 times; it is to calculate the average percentage of the training progress final validation accuracy. The final validation accuracy of every training progress is recorded in Table 2. From the result of 10 times training progress, the average final validation accuracy is 96.41%.

Training on single GPU.
Initializing input data normalization.

Epoch	Iteration	Time Elapsed (hh:mm:ss)	Mini-batch Accuracy	Validation Accuracy	Mini-batch Loss	Validation Loss	Base Learning Rate
1	1	00:00:15	30.00%	37.86%	1.0919	1.1578	0.0010
1	25	00:00:32	90.00%	82.52%	0.2868	0.3254	0.0010
1	50	00:00:45	90.00%	94.17%	0.1880	0.1467	0.0010
2	75	00:01:00	100.00%	99.03%	0.0274	0.0703	0.0010
2	100	00:01:12	100.00%	97.09%	0.0087	0.1322	0.0010
2	125	00:01:25	100.00%	98.06%	0.0047	0.0553	0.0010
3	150	00:01:38	100.00%	100.00%	0.0146	0.0688	0.0010
3	175	00:01:51	100.00%	97.09%	0.0068	0.1447	0.0010
3	200	00:02:04	100.00%	97.09%	0.0116	0.1038	0.0010
4	225	00:02:18	100.00%	94.17%	0.0126	0.1448	0.0010
4	250	00:02:32	100.00%	96.12%	0.0027	0.0835	0.0010
4	275	00:02:46	100.00%	97.09%	0.0036	0.1015	0.0010
5	300	00:02:58	100.00%	96.12%	0.0050	0.0870	0.0010
5	325	00:03:10	100.00%	99.03%	0.0024	0.0601	0.0010
5	350	00:03:22	100.00%	98.06%	0.0779	0.0718	0.0010
5	365	00:03:30	100.00%	96.12%	0.0805	0.1048	0.0010

Training finished: Max epochs completed.

Figure 4: Training info for each iteration

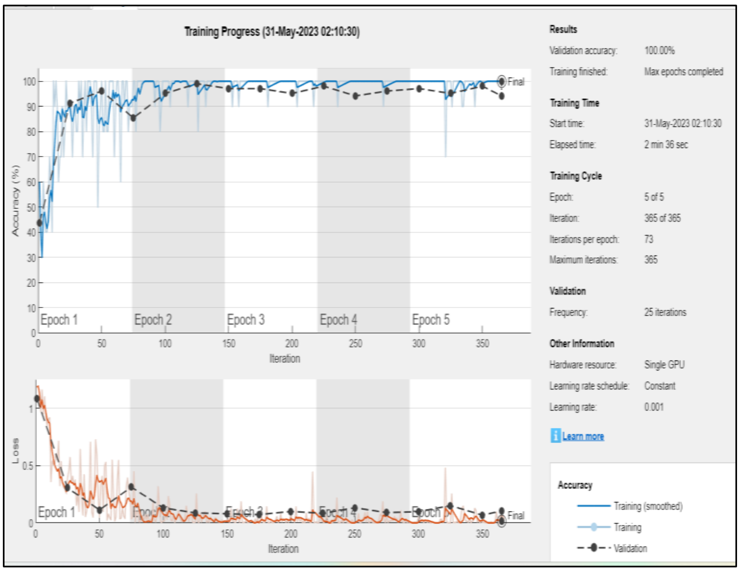

Figure 5: Training progress of image dataset

Table 2: Final validation accuracy of training progress

Image validation count	1	2	3	4	5	6	7	8	9	10
Final validation accuracy (%)	98.06	94.17	100	97.09	92.23	91.26	97.09	100	98.06	96.12

4.2 FFBs Ripeness Classification using Raspberry Pi Camera module on live images

The FFBs colour grading system was tested using live images. The camera module is placed in front of the bunches to calculate the accuracy of system 3 class of FFBs ripeness which are Ripe, Unripe and Overripe. The results were recorded, and a confusion matrix are done to calculate the accuracy, precision, recall and F1-score. The system was tested with 30 bunches at KOPDAP located at Parit Raja.

Table 3 shows the confusion matrix data recorded from 30 palm fruit bunches that were tested using the system. The true positive (TP) of each class is represented using blue colour while light blue colour represents the negative output. Since the results of the system test were recorded the precision, recall, F1-score and accuracy can be calculated. True positive (TP), true negative (TN), False positive (FP) and false negative (FN) value are calculated and recorded in Table 4.

Table 3: Confusion matrix for FFBs ripeness

Actual / Predicted	Ripe	Unripe	Overripe
Ripe	6	1	3
Unripe	0	8	2
Overripe	5	2	3

Table 4: Total of TP, TN, FP, and FN

	TP	TN	FP	FN
Ripe	6	15	4	5
Unripe	8	17	2	3
Overripe	3	15	7	5

Table 5 shows the accuracy of the system classified the class of palm fruit ripeness. The accuracy for Ripe class is 70%, Unripe is 83% which the highest and the lowest accuracy is Overripe that only achieve 60%.

Table 5: System accuracy for each group

	Precision	Recall	F1-score	Accuracy
Ripe	0.60	0.55	0.57	0.70
Unripe	0.80	0.72	0.76	0.83
Overripe	0.30	0.25	0.27	0.60

5. Conclusion

FFBs Colour Grading System Using Raspberry Pi is a system to classify FFBs ripeness grade by using hardware and software applications and from the evaluation result using the confusion matrix method. The accuracy of the Unripe class achieves the highest accuracy among other classes which 83% while the lowest accuracy recorded is 60% achieved by the overripe class. The result of this work indicates that using CNN with ResNet-50 can perform the FFBs colour grading system by using MATLAB and Raspberry Pi hardware.

Acknowledgement

The authors would also like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Malaysian Palm Oil Council, https://mpoc.org.my/malaysian-palm-oil-industry/

[2] ABDUL JALIL M. " Grading of FFB for palm oil mills in Malaysia" *Palm Oil Engineering Bulletin* No.39, p3-5, 1995

[3] What is Fresh Fruit Bunches (FFB) | IGI Global https://www.igi-global.com/dictionary/lean-logistics-of-the-transportation-of-fresh-fruit-bunches-ffb-in-the-palm-oil-industry/60511?

[4] N. Khamis, H. Selamat, S. Ghazali, N. I. M. Saleh and N. Yusoff, "Comparison of Palm Oil Fresh Fruit Bunches (FFB) Ripeness Classification Technique using Deep Learning Method," *2022 13th Asian Control Conference (ASCC), Jeju, Republic of Korea*, pp. 64-68, 2022

[5] Corley, R.H.V. and Tinker, P.B. (2003) *The Oil Palm. 4th Edition*, Wiley, Hoboken, 562 p. https://doi.org/10.1002/9780470750971

[6] Z. Hashim, H. Muhammad, C. K. Weng, C. Y. May, and M. B. Wahid, “Life Cycle Assessment for Oil Palm Fresh Fruit Bunch production from continued land use for oil palm planted on mineral soil (part 2),” *Journal of Oil Palm Research*, Dec-2010. [Online]. Available: http://jopr.mpob.gov.my/life-cycle-assessment-for-oil-palm-fresh-fruit-bunch-production-from-continued-land-use-for-oil-palm-planted-on-mineral-soil-part-2/

[7] E. A. B. da Silva and G. V. Mendonça, “Image processing,” Image Processing - an overview | ScienceDirect Topics, https://www.sciencedirect.com/topics/engineering/image-processing (accessed Jul. 15, 2022)

[8] Matt. (2016). Raspberry Pi Status LEDs Explained. Raspberry Pi Spy. https://www.raspberrypi-spy.co.uk/2013/02/raspberry-pi-status-leds-explained/

[9] M. Mishra, “Convolutional Neural Networks, explained,” Medium, https://towardsdatascience.com/convolutional-neural-networks-explained-9cc5188c4939 (accessed Jun. 27, 2022)

[10] A. Rastogi, “RESNET50,” Medium, https://blog.devgenius.io/resnet50-6b42934db431