Wearable Device for Malaysian Ringgit Banknotes Recognition Based on Embedded Decision Tree Classifier

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***Abstract*—The purpose of this project is to develop a wearable Malaysian Ringgit banknotes recognition device for assisting the visually impaired people to recognize the value of Malaysian banknotes. In this project, the RGB values in six different classes of the banknotes (MYR 1, MYR 5, MYR 10, MYR 20, MYR 50 and MYR 100) were taken at 12 different points (6 upside, 6 downside) using colour sensor (TCS 34725) before three features called RB, RG, and GB were extracted from the RGB values. After that, these features are used to model the embedded Decision Tree Classifier (DTC) in Matlab for recognizing each classes of banknote. Cross validation with 10-fold was used to select the optimize DTC which is based on the smallest cross validation loss. The performance of optimize DTC model is presented in confusion matrix and compared with Naïve Bayesian and k-Nearest Neighbour classifier before this model is implemented in Lilypad Arduino. The performance of the device in term of accuracy is evaluated by asking 10 subjects to use the device. Result shows that the proposed embedded optimize DTC model managed to achieve 84.7% accuracy which outperforms other classifier. In conclusion, proposed device is successfully developed and it should be possible, therefore, to integrate other features (instead of colour) in recognizing the ringgit banknote.**

***Index Terms*—Banknotes Recognition; Cross-validation; Decision Tree Classifier, Lilypad Arduino**

I. INTRODUCTION

Several investigations have been done in developing the assistive technology for the blind people so that they can independently complete their daily tasks. In general, the assistive technologies development for blinds can be folded into two categories:- 1) information transmission; and 2) mobility assistance [1]. Information transmission mostly used in reading, character recognition, graphic information and also object recognition for the blinds [1]. For the mobility assistance, the system is much more complex because it requires spatial information of the environment, orientation and obstacle avoidance [1]. Both supportive systems are integrated with tactile and hearing sensory to substitute visually impaired capable of vision in order to interpret the information.

In information transmission based assistive technology, banknotes recognition system is one of the interventions that can help the blinds to do daily task activity such as grocery activities by themselves. This system can help the blinds to classify the value of the banknotes and it can be divided into two class of modality system which is sensor-based modality [2-4] and vision-based modality system [5-10]. For example, several banknotes recognition system for Saudi Arabian, Egyptian, Persian, Indian, Australian, Hungarian, Mexican, Sri Lankan, and Malaysian were introduced with several different techniques and features extraction.

In Malaysia, study in [2] proposed the banknotes recognition system by using sensor-based modality. However, it uses Arduino UNO as the processing part which makes it bulky and not suitable to be a wearable device for the user. Besides, the rule-based approach that was used in recognizing the banknotes is subjectively defined and there is no machine learning or classifier intervention in interpreting the banknotes. While in other countries, there had been various devices that can help the blinds to identify the value of banknotes. Unfortunately, the existing device can only recognize one sort of currency [11]. In addition, most of the banknotes recognition system which is based on vision-based modality is suffered computational complexity that required more processing time and high power consumption in the recognition process [12].

Therefore, a wearable device for Malaysian Ringgit banknotes recognition using embedded decision tree classifier had been proposed in this project in order to help the visual impairment to recognize the value of Malaysian banknotes. The embedded decision tree was modelled in Arduino Lilypad which obtain the color information (RGB) from the color sensor (TCS 34725). The performance of decision tree in recognizing the banknote was evaluated using 10-folder cross validation and compared with k-Nearest Neighbour (k-NN) and Naïve Bayesian classifier.

II. LITERATURE REVIEW AND RELATED WORKS

A. Assistive Technology for Visually Impairment

The life quality of people with visual disabilities has been improved with the advancement of technologies nowadays. It is vital for the visually impaired people to get the perception of the surrounding environment in facilitating them through their daily life such as in doing the personal care, environmental control/household appliances, money, finance and shopping [11]. Different methods and sensors are presented in the assistive devices to give the perception of the environment and the detection of objects to the visually impaired. In general, the development of assistive technology for blinds can be folded into: 1) information transmission; and 2) mobility assistance [1].

Information transmission is the supportive systems to help the visually impairment to get the information from reading, character recognition, and object recognition. Mostly, the system permit character and graphic recognition by translate it to the user through their tactile sense. Braille is one of the most successful ways of information transmission that had been invented to the blinds [1]. Study in [13] also proposed the information transmission system of blind-assistant object finding by using camera-based network and matching-based recognition algorithm to find the personal items of the blinds. The system used the camera to recognize the object by compare the captured objects with the reference object image samples in the dataset [13]. For the independent experience for the blinds to do grocery shopping, Trinetra [14] is one of the portable barcode reader that operates using text-to-speech software and RFID tags to recognize a product. Once the product is identified, the description will be delivered to the user via the synthesized speech. With this kind of technology, the visual impaired do not need to ask the assistance from other person to find and identify their needs. Moreover, in the information transmission, banknote recognition system is one of the interventions that can help the blinds to do daily task activity such as grocery activities by themselves [10]. This banknote recognition system can help the blinds to classify the value of the banknotes and the ability to manage money and shopping by themselves.

For the mobility assistance, the surrounding and information from environment will be scanned, gathered and presented to the blinds through tactile or hearing interface in order to ensure safe and independent mobility for the visually impaired people [1]. Many electronic travel aids (ETAs) have been proposed to improve and guide the mobility of visually impaired in this continually changing and unfamiliar environment [1]. For example, Bionic Eyeglass [15] is one of the devices that help the blinds in their mobility as personal navigation system by converting the visual information of the environment into the audio signal. Study in [16], proposed a tactile sensory substitution device called as the EyeCane which was developed to aid the blinds in obstacle identification and avoidance in an unobtrusive manner. It uses a narrow-beam approach to provide the user with accurate information about the environment and transform the information through tactile and auditory output according to the distance of user from the objects.

Therefore, in this project, information transmission based assistive technology will be used as the supportive system to help the visual impairment person in detecting the banknotes by providing them with auditory output from the cueing module to differentiate the banknote.

B. Banknote Recognition for Visually Impairment

In information transmission based assistive technology; banknote recognition device is one of the important devices that can help the blinds perform the grocery activities. Commonly, the studies related to banknote recognition can be fragmented into: 1) sensor-based modality; 2) vision-based modality. Sensor-based modality system use sensor that works in RGB color detection to determine the banknotes color while the vision-based input system used banknote image took from camera or scanner in recognizing the value of banknote.

In sensor-based system, MoneyTalker [3] was introduced to classify the Australian banknote. The device recognized the banknotes by annunciates its value through speaker or headphones using electronic speech. This type of technology for sure can aid and support the blind person to do grocery activities by themselves but the limitation is, it can only be used to identify the Australian currency banknotes. Study in [4] introduced Light Dependent Resistor (LDR) sensors and Light Emitting Diode (LED) Lights for recognizing the banknotes. Colour patterns and length were used to classify different banknotes before executing the audible cue. The system developed may have successfully recognized the banknote, but the limitation was the banknote had to be placed in a correct fixed position. Otherwise, the error message would play and the banknote cannot be identified. Mohamed A. et al. [2] proposed the colour sensor TCS230 for detecting the different colours of Malaysian banknotes using the obtained RGB information. The input that was taken from the TCS230 was processed by the ATMega328P-PU microcontroller, and then the banknotes were identified via the colour recognition method. The developed system required the user to do more hand interaction because it is portable, rather than wearable whereby the user can use less hand interaction with the device [1]. The banknote recognition also may seem too bulky because it used Arduino UNO as the processing part. Therefore, banknote recognition device based on Arduino Lilypad has been proposed in this study which provides a lot of advantages especially in designing a wearable based assistive technology.

For vision-based modality system, Sarfraz's [6] introduced the banknotes recognition system with a high resolution scanner to acquire the image of the Saudi Arabian banknote. Although the system showed highly accurate result, the processing time was increased due to its complex network. Another study that used scanner was developed by Ahangaryan F. P. et al. [7]. This Persian banknote recognition system applied wavelet transform as the feature extraction and neural network as the classification method to determine the banknote from the input image. Instead of scanner, there are also several investigations that proposed camera as a medium to obtain the image. For instance, study in [8] used the mobile camera with resolution of 480x320 pixels to detect the image of the banknotes. Tactile marks of Hungarian banknotes were used to extract the feature that can identify different types of banknote. Moreover, study in [5] also used a digital camera to recognize the Egyptian currency. Several image processing techniques such as segmentation, histogram enhancement and region of interest were used before ended with cross-correlation technique between the captured image and database image to classify the Egyptian banknotes. Besides that, study from [9] implemented MSURF algorithm in recognizing the features of the Indian banknotes. The MSURF algorithm is a complex process that can extract the feature points of the Indian currency above 160 pixel range. García-Lamont, F. et al. [10] proposed RGB space technique in recognizing the Mexican banknotes.

In conclusion, vision-based system requires high power consumption and took more time to process because of its complex feature extraction and classification. Image processing method is applied in order to determine and extract the features of the banknotes. The system usually used camera or high resolution scanner in order to get the best image of the banknotes. As a result, the development cost for vision-based system is higher than the sensor-based system.

C. Decision Tree Model as Classifier

Decision tree is a classifier that will produced branch-like segments from the algorithms by identifying various ways of splitting a data set. It attempts to find a strong relationship between input values and target value so that the splitting rules are applied one after another, resulting in hierarchy of branches within branches that produces the characteristic of inverted tree with a root node at the top of the tree and leaves (terminal nodes) at the bottom [17]. The input to the classifier is a training set of records, which is tagged with a class label [18].

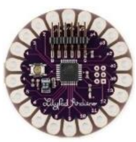
When a decision tree is built, many of the branches will reflect anomalies in the training data due to noise or outliers. This problem is called as overfitting and it will results in poor accuracies. Two methods which are: 1) Choosing the minimum leaf size in modelling the decision tree that produce the smallest cross-validation error; and 2) Tree pruning methods can be used in order to optimize the performance of classifier by reducing its branches. Typically, it will use statistical measures to remove the least reliable branches and improve the correctly classify test data in a higher accuracy rate rather than before optimization.

III. MATERIAL AND METHOD

A. Material and Technical Description

The materials used in developing this device are represented as simple systems which include an input part, a processing part and an output part. For the input part, this device used the RGB colour sensor with IR filter which also known as TCS34725. This sensor can be used to detect the different colour of the banknotes. It has RGB and Clear light sensing elements. It operated as an infrared blocking filter, integrated on-chip and localized to the colour sensing photodiodes, minimizes the IR spectral component of the incoming light and allows colour measurements to be made accurately [12]. Then, the information from the sensor will be processed by the microcontroller part which is the ATmega168V in Arduino Lilypad Main Board. The decision tree classifier model was embedded in this board in recognizing different types of banknote based on reading given by the input.

Table 1
Main Components in Developing the Device.

INPUT	PROCESSOR	OUTPUT
		
TCS34725 RGB Colour Sensor with IR filter as the input part.	LilyPad Arduino Main Board as the microcontroller and processing part.	Lilypad Buzzer as the cueing module to represent each banknote with different notes

Lastly, the result of the value for banknotes was enunciated through the cueing module. The recognition process for the banknotes is fast as the cueing module will produced different kinds of notes sound that will represent each banknote. In this project, Lilypad Buzzer that produced different kinds of notes was used to give cue to the visually impaired person to represent the value for each of the banknotes. The person need to place the banknote to the device and push the button to get the result from the cueing module. Table 1 shows main components that will be used in developing this device.

B. Methodology

There are four main processes that needs to be done in producing the Malaysian banknotes device: 1) data acquisition and collection; 2) data analysis; 3) system development; 4) system evaluation.

During the data collection, the R, G, and B values for each Malaysian banknotes was recorded using the colour sensor. These values were taken at twelve points (see Figure 1) which is six points at the upside and six points at the downside of the banknotes. Five different sets of banknotes which consist of RM 1, RM 5, RM 10, RM 20, RM 50 and RM 100 per set are used during the experiment in order to collect the data. This means that each class will have 60 data points of R, G, and B values. After that, the features called RB, RG, and GB are calculated according to the following equations:

$$RB = R - B \quad (1)$$
$$RG = R - G \quad (2)$$
$$GB = G - B \quad (3)$$

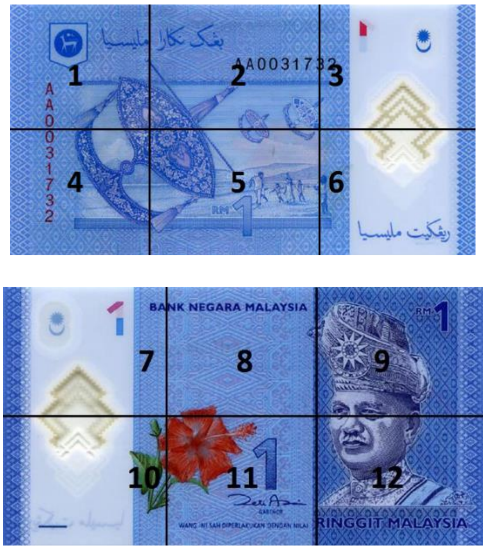


Figure 1: RM 1 banknote sample with 12 points used to collect data for R, G, and B values.

Next, for the data analysis, the three features (RB, RG, and GB) were used as the main features in modelling the DTC using MATLAB. Cross validation with 10-fold was used in this process to utilize as much data as possible for training proses. In this project, cross validation was used in selecting the optimum DTC by varying the minimum leaf size. After producing the optimum DTC, the performance of this model was compared with other classifier model which are Naïve Bayesian and k-Nearest Neighbor.

In system development, there are two things that need to be done which is the internal and external part. The internal part consists of the processor and programming part which model the optimum DTC in Arduino Lilypad. For this part, the rule-based algorithm that generated from optimum DTC was implemented in Lilypad Arduino. The rule-based algorithm as well as other functions will operate according to the flowchart as illustrated in Figure 2. The external part related to the designing the shape of the device. Solidworks software was used to develop the 3D design of the banknote recognition device.

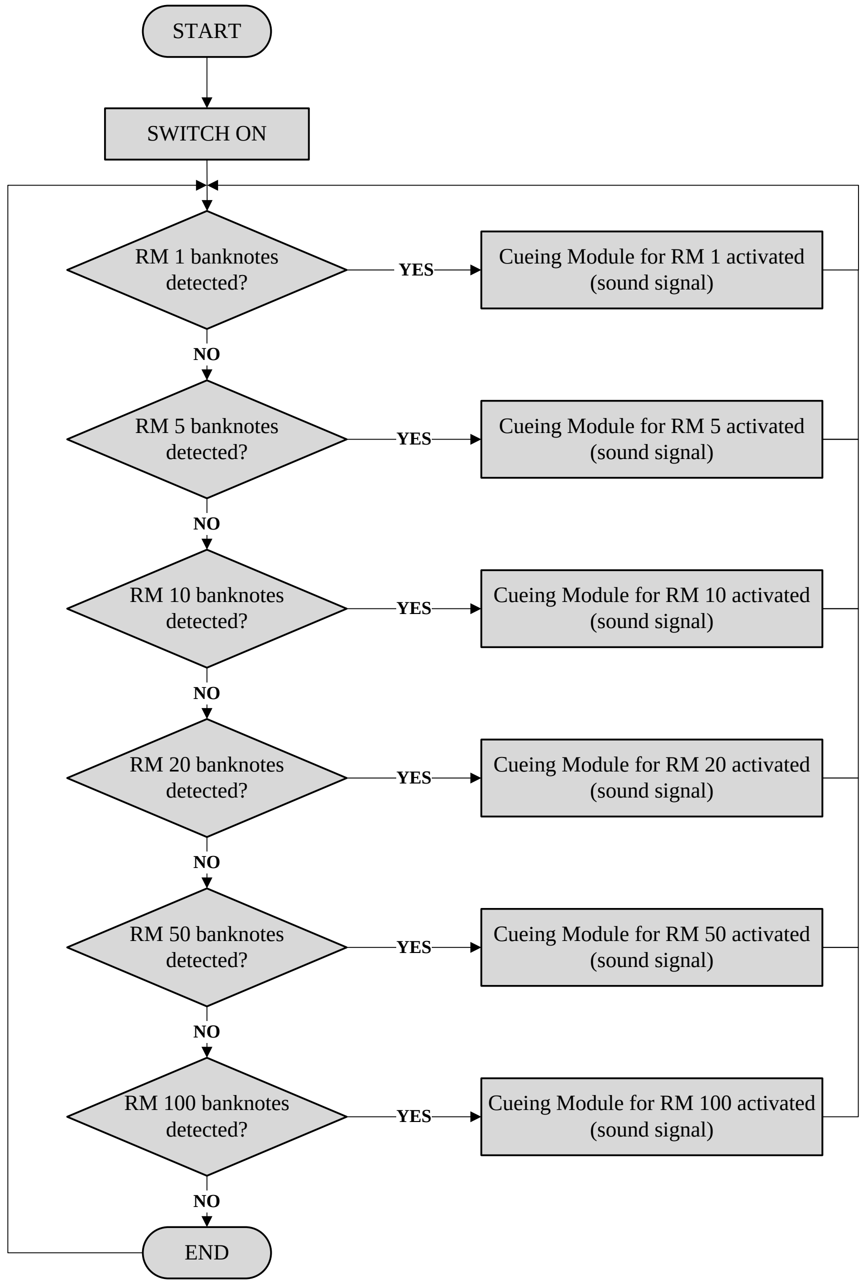


Figure 2: Flowcharts on the operation of the Malaysian banknotes recognition device.

Lastly, once the system was developed, 10 subjects were used to test the device. The subject was asked to point the device at 12 different locations for each type of ringgit banknote. From the result, the performance of the device in terms of accuracy is calculated using the following equation:

$$\text{Accuracy} = \frac{\text{Number of correct result}}{\text{Total number of trials}} \times (100\%) \quad (4)$$

IV. Result And Discussion

In data analysis process, the RB, RG, and GB values were used as the features in modelling the DTC. Figure 3 shows the overall result of DTC model using the minimum leaf size of 10 (default value in Matlab function). In order to obtain the optimum DTC, cross validation losses from different DTC with different minimum leaf size were formulated using the 10-folder cross validation approach. Minimum leaf size will determine the complexity of the produced DTC model. Large number of minimum leaf size will reduce the growing process which make the tree has less branches and reduce the complexity. The cross-validation loss versus the minimum leaf size graph is presented in Figure 4. From this figure, it can be concluded that from the minimum leaf size 1 to 47, the smallest cross-validation loss produced is when minimum leaf size is equal to 20. Thus, this model (with minimum leaf size = 20) is selected which produce the DTC model with less complexity as compare to previous and appropriate to be modelled in embedded system (Arduino Lilypad in this case) instead of producing less cross validation loss. Figure 5 presents the optimum DTC model produced when the minimum leaf size is 20.

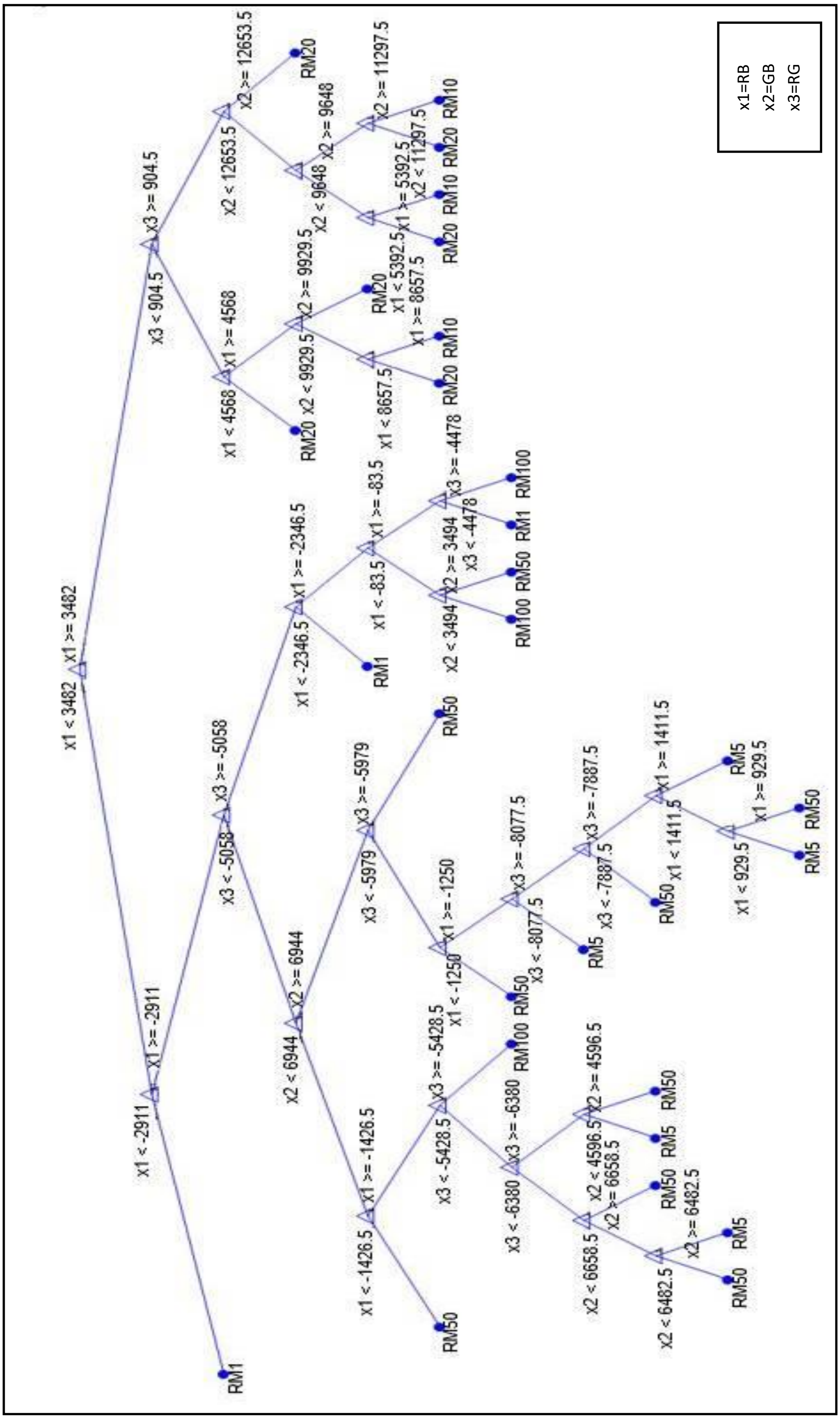


Figure 3: Overall result for Decision Tree Classifier.

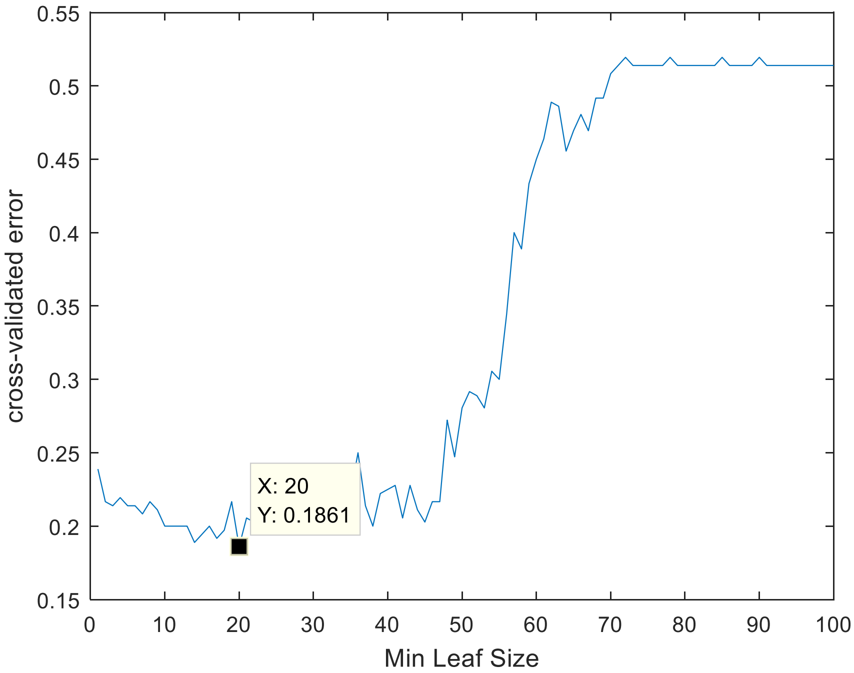


Figure 4: The cross-validated error is the lowest when the minimum leaf size is 20.

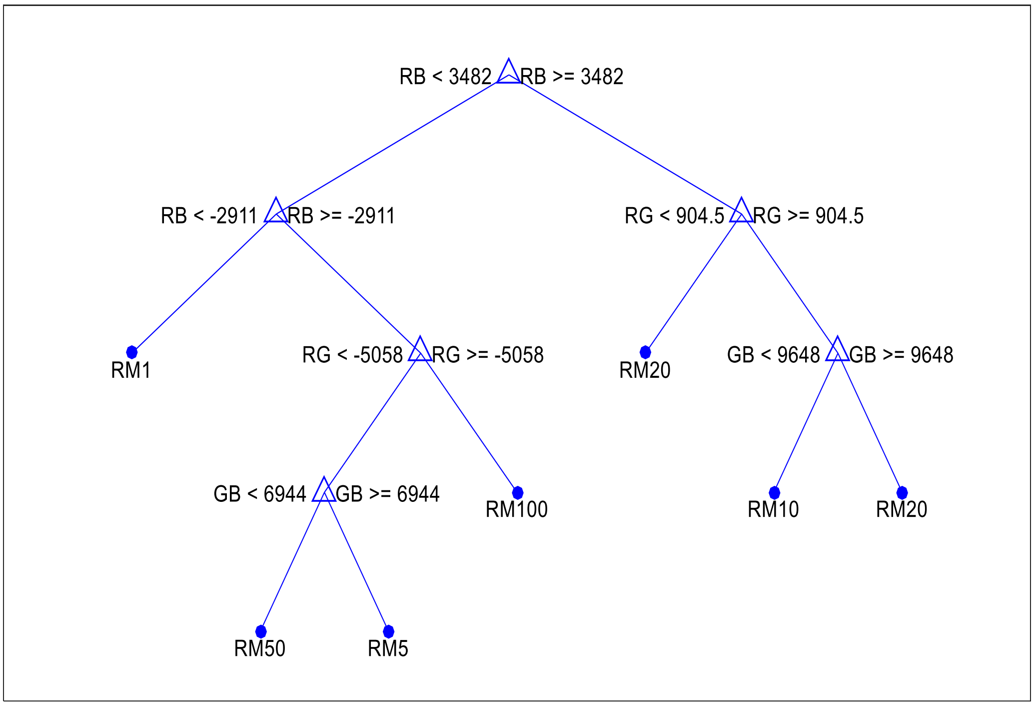


Figure 5: The optimized DTC after applied minimum leaf size = 20.

Figure 6, 7 and 8 show the confusion matrix that represents the performance of the optimum DTC model, Naïve Bayesian and k-Nearest Neighbour classier in recognizing different types of banknote. Overall, the proposed optimum DTC outperforms other classifier with accuracy, 84.7%. By highlighting within classes performance, it can be interpreted that all classifiers suffer with sudden performance degradation in class 1 (MYR 5) and class 5 (MYR 50). This is perhaps due to the green as a dominant colour component for both banknotes which result a few banknotes of MYR 5 are misclassified as MYR 50 or vice versa.

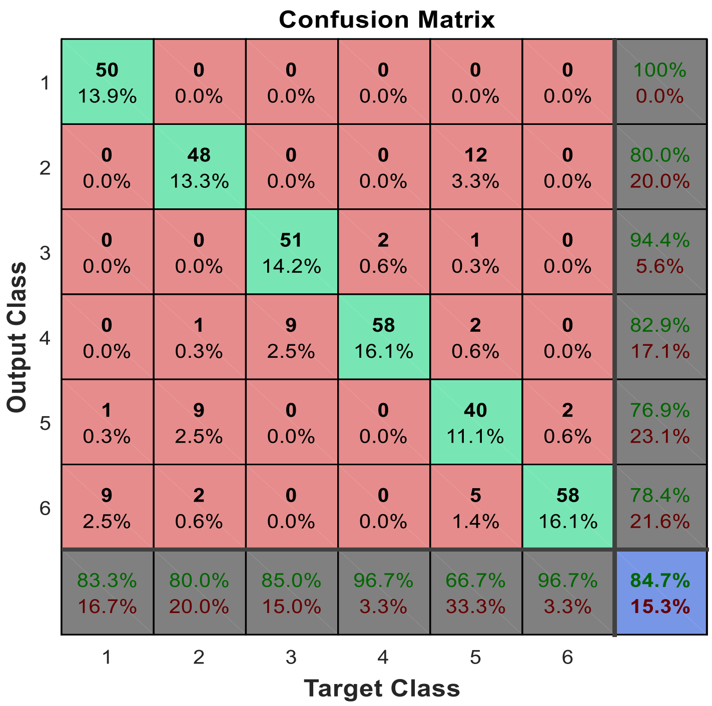


Figure 6: The confusion matrix in classifying the banknotes using optimized DTC.

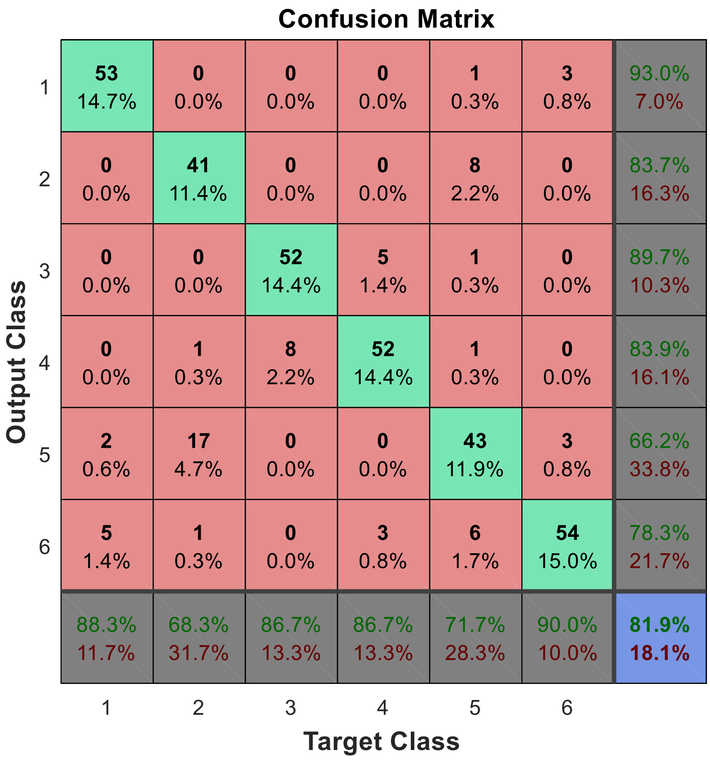


Figure 7: The confusion matrix in classifying the banknotes using Naïve Bayesian classifier.

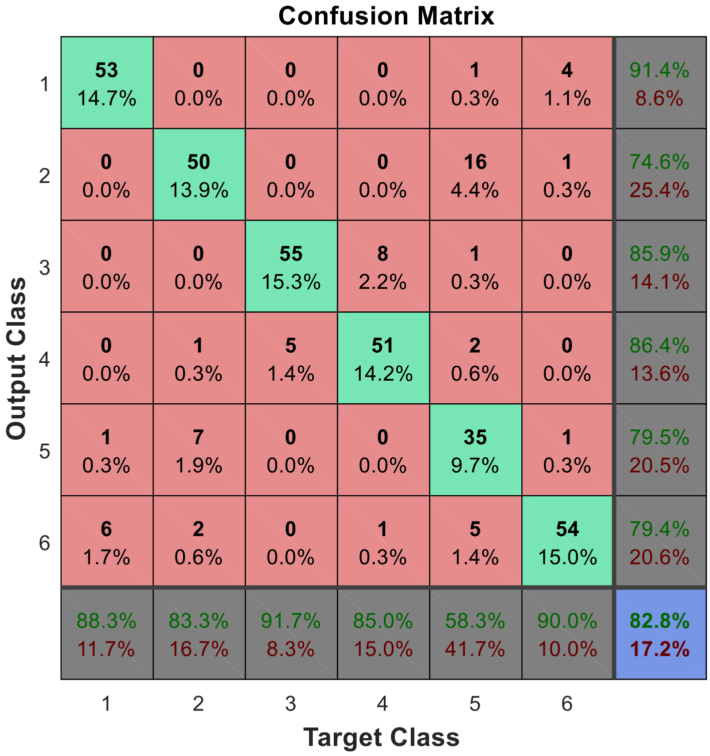


Figure 8: The confusion matrix in classifying the banknotes using k-Nearest Neighbour classifier.

As mentioned in previous section, system development stage can be divided into two parts which is internal and external part. For the internal part, it consists of the rule-based generated from the optimum DTC model which is implemented in the Arduino Lilypad. For the external part, Figure 9 and Figure 10 illustrate the design of the wearable Ringgit banknote recognition device that is sketched in 3D using Solidworks software (Figure 9) and printed design (casing of the device). This banknotes recognition device is designed in a small circle-shaped as a necklace as it will be a wearable device.

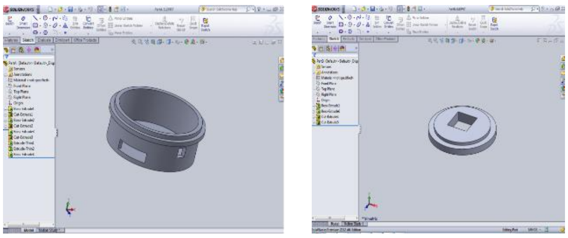


Figure 9: Solidworks sketches for the casing of banknotes recognition device.

Figure 10: The 3D printed casing for the banknote recognition device.

As mentioned in the previous section, 10 subjects are asked to test the developed device. Each subject need to use the device at 12 different location of each banknote. Figure 11 presents the accuracy of each banknote value which is calculated using (4). Overall, it seems that the accuracies values are identical to the confusion matrix in Figure 7 which shows that MYR 5 and MYR 50 provide the major contribution in reducing the performance of the device.

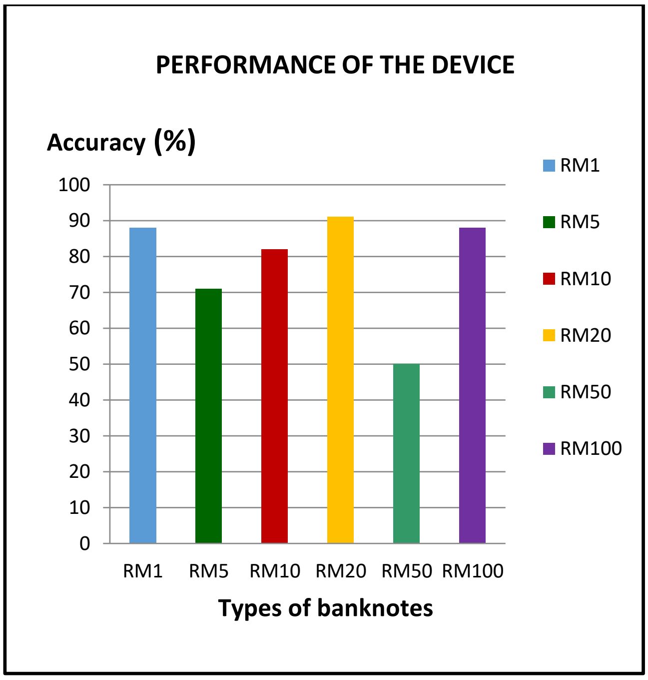


Figure 11: The accuracy of the proposed device.

V. Conclusion And Future Work

In conclusion, a wearable Malaysian Ringgit banknotes recognition device that use colour sensor and embedded decision tree classifier including the cueing module has been developed in order to help visual impairment person to recognize the value of Malaysian banknote. The proposed optimize DTC outperforms the Naïve Bayesian and k-Nearest Neighbour classifier in recognizing different type of Malaysian Ringgit banknote with accuracy of 84.7%. However, the proposed optimize DTC is in good agreement with other classifier in suffering with sudden degradation due to the misclassifying of a few banknote of MYR 5 as MYR 50 or vice versa.

From this banknote recognition device, the visually impaired people can improve their quality of life by reduce the dependency to other people in completing their daily tasks and routine especially in the grocery activities. Instead of its low cost and low power consumption, the device also is in lightweight and can be worn by the users in performing the grocery activities. Moreover, in future work, it should be possible therefore to integrate other features such as size of the banknote or other features (instead of colour), as the additional features in recognizing the ringgit banknote.

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