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Compared RGB Methods Towards Efficient Money Detector for Blind People

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ABSTRACT Limitations of profound visual impairment distinguishing each nominal number of banknotes are often used by people with bad intentions to take advantage of that basis, like money fraud. Due to this reason, the blind people need to be helped to recognize their surroundings by developing assistive technology that is advanced for them. This study aims to build an efficient design of a money detector by comparing three RGB methods: range breakdown, If-Then Rules, and decision tree to recognize the nominal of money. By comparing the RGB methods, this research contributes to investigate the most accurate and efficient method for further development of money detector for blind people. The sample used in this experiment is rupiah banknotes for the 2016 and 2022 issuances. The device is built with a TCS3200 colour sensor and designed in a real-time platform. It has been found that the highest average percentage accuracy was achieved by the breakdown range method with 100% (2016 sample) and 90% (2022 sample). This device also successfully produced a notification sound from a speaker that mentions the detected nominal value. This research could be used as a reference to improve assistive technology for blind people.

INDEX TERMS RGB, Breakdown, If Then Rules, Decision three, Blind

I. INTRODUCTION

Money is an essential economic instrument. Almost every economic activity in the world is very dependent on roles money. One type of money that is often used is paper money. Indonesia is issuing rupiah banknotes to be used as a medium of exchange for legal payments in all regions[1]. However, the use of paper money Rupiah as a means of exchange for payment cannot be appropriately used by everyone, especially blind people[2].

Blindness is a condition in which a person has no senses and his vision does not function normally, which is caused by injury or damage, both structural and functional [2], [3]. According to the data obtained from PPLS (Social Protection Program Data Collection) in 2012, the population of Blind people in Indonesia is estimated to number around 142,860 people[4]. Meanwhile, the estimated data according to the Ministry of Health of the Republic of Indonesia, the number of blind people in Indonesia reaches 1.5 per cent of the entire population[5]. If Indonesia's population is currently approximately 250 million people, it means that there are around 3,750,000 blind people. Both included the category of blind and visually impaired [6].

In this research, the author created a system that can detect nominal rupiah banknotes for the 2016 and 2022 emission years based on the reading of the RGB value contained in each money by utilizing the TCS3200 colour sensor and calculating it inward each range of RGB values that can represent each nominal amount of money paper used.

By using Arduino Nano as a microcontroller, this system will have an output in the form of sound from the speaker connected. The use of Arduino Nano in previous research worked as a data acquisition system to retrieve, collect, provide commands, and prepare data according to the program that has been created to operate it to produce the desired data. TABLE 1 resume the comparison between the developed research for detecting Rupiah paper money and this study.

To recognize colour one technology in the field of electronics is TCS3200 colour sensors, which can be used for a variety of interests, such as analyzing several colour object [7]–[9].

TABLE 1
The comparison between the developed research for detecting Rupiah paper money and this study.

Methods	Result	Adavatages	Limitations	Components	Ref
Blackbox Testing	The success rate is around 80% in detecting the nominal value of 2000 banknotes	Can detect the authenticity of 2000 banknotes	There is still light entering which affects the reading of the RGB values	TCS3200-DB Sensor, Ultraviolet Sensor, Arduino Uno	[10]
RGB Value Detection	The output is in the form of analog data for detecting the authenticity of money and displaying the nominal value of money on the LCD as well as sound	Can produce output in the form of LCD and sound to ensure the authenticity of the money	The money used is only from one edition	Light Sensor, Ultraviolet Lamp, LM2596, TCS3200 Sensor, LCD, Speaker, Arduino Uno	[11]
Qualitative	The denomination of the detected banknote is displayed on the LCD screen and the loudspeaker also makes a sound representing the value of the banknote in rupiah	The sensor accuracy value is 95.7% according to the test results	Still using the old type of color sensor	TCS230 sensor, Arduino Uno, Loudspeaker, LCD, DF mini player	[12]
Blackbox Testing	A system capable of detecting nominal rupiah banknotes from 1000-100000 as well as $1 and $10 dollar banknotes	Can determine the nominal amount of money based on RGB colors (Red, Green, Blue) and produce the sound of the nominal money	The tool design is yet simple and minimalist	TCS3200-DB sensor, Arduino Uno, Serial mp3 player, speakers	[13]
Breakdown RGB, If-Then Rules, Decision Tree	**The tool is able to detect nominal rupiah banknotes issued in 2016 with an accuracy up to 100% and emissions in 2022 with an accuracy of 90%**	**Minimalist tool design with the use of a rechargeable power supply**	**The design for placing the money is still small and there is no alarm for the charging indicator.**	**TCS3200 sensor, Arduino Nano, DF miniplayer, speaker, 18650 battery**	**This Work**

The TCS3200 colour sensor has an output in the form of digital data in the form of pulses from the results of colour readings. This sensor also can integrate with four LEDs. Regarding specification, it has a supply voltage of between 2.7 volts to 5.5 volts. This sensor is not linear and has a sensibility which can change with the measured wavelength[14]–[16] .

The objectives of this research could be resumed as (1) designing a money detection tool for blind people using the Table 2 The comparison between the developed research for detecting Rupiah paper money and this study.
RGB breakdown method, If-Then Rules method, and decision tree method; (2) testing the accuracy of the tool based on detecting the colour of various money side; (3) finding out the accuracy of the TCS3200 colour sensor and speaker in detecting nominal money. It has not been reported yet the investigation comparing RGB method to seek the most accurate and efficient ways. Moreover, this detector is built with minimalist design and applied to the rechargeable power supply. This research has contribution including:

a. Studying the comparison of the RGB methods to seek the more efficient way.
b. Developing a tool capable of detecting nominal rupiah banknotes based on colour using a TCS3200 colour sensor, which has sound output.
c. Helping blind people know and recognize the nominal value of rupiah banknotes more accurately and independently to minimize the occurrence of mistakes in transaction activities. and
d. This study could be use as reference to further development of assistive technology to detect banknotes especially for disabilities for instance the blind people.

II. METHOD

In this research, a money detection tool was designed for the visually impaired using an RGB-based comparison method, Arduino Nano. This research designs a system that can recognize nominal rupiah banknotes for 2016 emissions and 2022 emissions based on the reading of the RGB value contained in each rupiah banknote by using the TCS3200 colour sensor. The process is by calculating the inward of each range of RGB values that can represent each nominal amount of money paper that is tested.

By using Arduino Nano as a microcontroller, this system will have an output in the form of sound from the connected speaker. This research has upgraded compared with the previous research on the aspect of using voltage supply and parallelly compared the three methods to study which method is more efficient regarding accuracy and complexity. The method of this experiment could be classified into three steps, including designing the system, collecting the data, and assessing the RGB method.

A. SYSTEM DESIGN

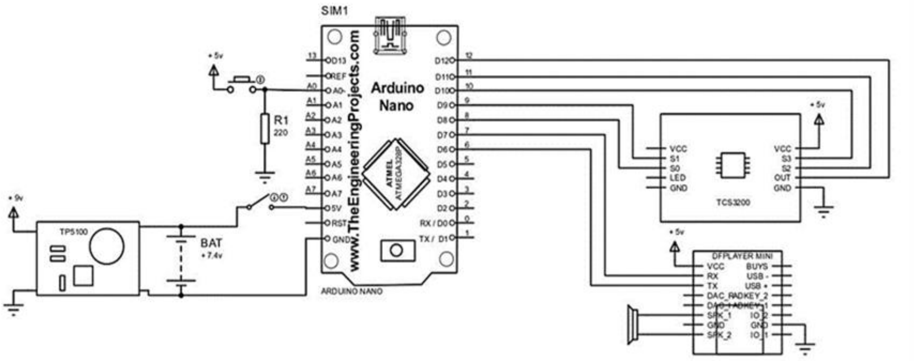

FIGURE 1. The wiring system of money detector

In system design, the stage of creating wiring diagrams and schematic circuits clarifies the wiring system and connections between pins that will be made during hardware design. The wiring diagram in FIGURE 1 illustrates the wiring system for all components that will enter the hardware design stage, with the main component of Arduino Nano as a microcontroller to

xx make the system able to operate according to predetermined procedures. In the wiring diagram, pin S0 to pin S3 on the TCS3200 sensor relates to pin D8 to pin D11 on the Arduino nano, where pins S0 and S1 is a pin that functions to convert current to temporary frequency pins S2 and S3 function to determine the colour captured by the sensor. Apart from that, the pin out on the TCS3200 sensor is connected to pin D12 on the Arduino nano. The pin out of the TCS3200 sensor will become input to the microcontroller so that the data obtained can be processed in it.

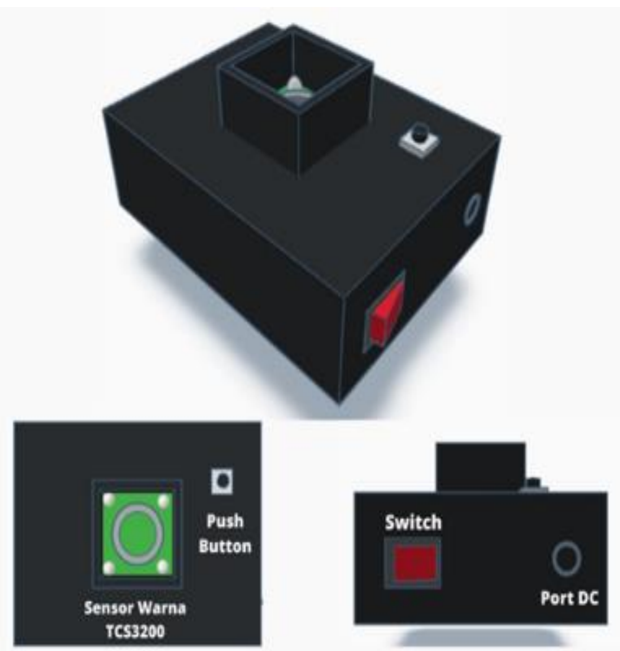

FIGURE 2. Design of money detector for blind people

This system design also uses an ON/OFF switch as this switch, and the push button is used as a trigger when retrieving colour data. FIGURE 2 shows the design of a money detector that developed in this research. The processing that occurs on the microcontroller is used for sending commands and receiving data from the DF minelayer via the RX and pins (FIGURE 3). TX is connected to pin D6 and pin D7 on the Arduino Nano. Arduino Nano will send a command to the DF mini player to play the mp3 file via pin D7, which is connected to pin RX. Then, from pin TX on DF, the mini player sends commands so that the speaker can produce sound; the command is sent via a microcontroller. The power supply used in the design of this system uses two types of batteries. One is lithium 18650, which can supply a voltage of 3.7 to 4.2 volts.

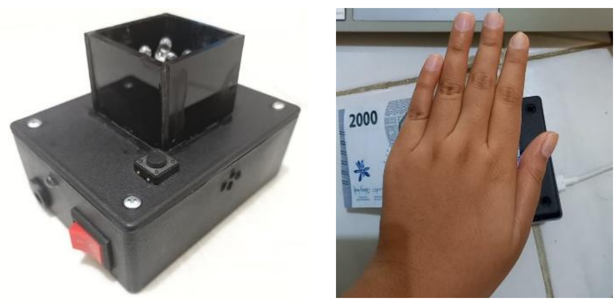

FIGURE 3. Money Detector Device and Its implementation

B. DATA COLLECTION

Several data collections were carried out in this research. These stages begin with retrieving RGB range data for each. Nominal rupiah banknotes that are used are issued in 2016 and 2022 collection. The RGB data range will be carried out on six sides of the money, including the left side bottom, bottom centre, bottom right, top left, top centre, and top right. Data The RGB range that has been obtained will then be tested to find out the performance of the tool in detecting the nominal value of banknotes rupiah. Initial testing was carried out without using speakers first by looking at the detection results in the serial monitor section found on Arduino IDE. This aims to determine the results produced by

TABLE 2
Initial data from the results retrieval of RGB values

Red	Nominal	Total	Green	Nominal	Total	Blue	Nominal	Total
38	5.000	1	**44**	1.000	1	**34**	10.000	3
43	1.000	1	**45**	2.000	1	**43**	1.000	1
44	2.000	1		5.000	1		2.000	2
47	10.000	1	**47**	10.000	1		5.000	1
48	5.000	1	**49**	2.000	1	**48**	5.000	1
49	2.000	1	**53**	5.000	1		1.000	1
	10.000	2	**57**	1.000	1	**49**	5.000	1
52	1.000	1		2.000	1	**53**	1.000	1
	2.000	1		5.000	1	**56**	2.000	1
	5.000	1		10.000	1			
59	1.000	1	**59**	1.000	1			
	Entropy= 0,68			**Entropy= 0,834**			**Entropy= 0,667**	

the tool at the time of detection. If the test is successful, then further data can be carried out using the speaker as output in the form of sound. In this data collection, ten times were carried out for each nominal by placing banknotes on various sides to find out which side is considered accurately detected. Data collection was carried out ten times for each. The nominal is divided into five parts on each side of the banknote. This is a detection flow that starts from the bottom of the money paper. These parts represent each corner of the banknote. This scenario is provided to represent the random position of money that is tested by blind people. Figure 3 shows the actual detector device and how it can be implanted.

C. RGB METHODS COMPARISON

Breakdown methods mean a breakdown of global data into details that have more measurable value. In this research, an RGB breakdown is used to detail each red, green, and blue value contained in each nominal value of rupiah banknotes issued in 2016 and 2022. The aim is to get the minimum and maximum values in each colour. Standard deviation testing is carried out with the aim of finding out how reproducible the resulting data is. This test aims to determine consistency as a tool for reading the RGB values contained in 20,000 nominal banknotes on the bottom left side. This is due to the average accuracy percentage produced by each test method used having different results and still being in small numbers. This test is done by looking at the results on the Arduino IDE serial monitor.

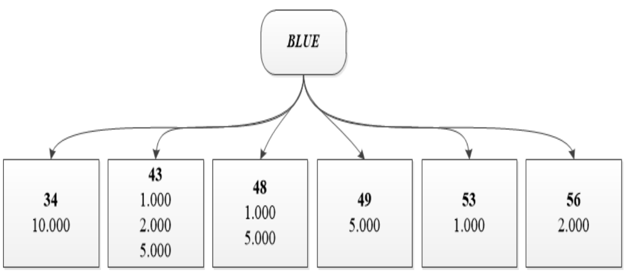

FIGURE 4. Initial tree arrangement

In this research, a decision tree is used to determine the range of the colour of the banknote, which can represent each denomination using the RGB range data that has been obtained and then presented in the form of rules. The results of this decision tree calculation will also be obtained in the form of rules, which will be used as internal data testing using the if-then rules method and the decision tree method.

The concept of data in a decision tree is expressed in table form with attributes and records, where the attribute states a parameter that is created as a criterion in tree formation[17]–[19]. The process in a decision tree starts from changing the data form (table) into a tree model, then changing the model tree becomes a rule, and simplifies the rule (pruning)[20]–[22].

1. CONVERTING DATA INTO A TREE

At this stage, it is done by determining the selected nodes with the entropy value of each sample data criterion specified in where the selected node is taken from the criteria with the smallest entropy value. The data used in TABLE 2 is initial data from the results retrieval of RGB values on the bottom left, bottom centre, and bottom right for a nominal value of rupiah banknotes from IDR 1,000 to IDR 10,000. The RGB values are taken on the bottom three sides of the banknote, which intends to find the possibility of which side it will be detected by the tool at the time the detection is carried out.

2. SELECTING THE STARTING NODE

The initial node selection is carried out to determine the first variable that will be used in the tree model by classifying all the data. The RGB sample range contained in Table 3 is based on colour components and their value. From the process of classifying RGB sample range data based on components' colours and values, as listed in Table 3, initial node selection can be determined by looking at the results of small entropy calculations. At the initial node selection stage, the first variable in creating a tree model is a blue component, along with a value component. From the results of determining leaf nodes using data classification as well, Entropy calculations have been carried out for the red and green colour ranges. The values blue 43 and blue 48 were selected as leaf nodes because they have the smallest entropy.

TABEL 3
The RGB sample range

Nominal	Money Side	R	G	B
1.000	Left Bottom	43	44	43
	Central Bottom	59	59	48
	Right Bottom	52	57	53
2.000	Left Bottom	52	57	56
	Central Bottom	44	45	43
	Right Bottom	49	49	43
5.000	Left Bottom	52	45	43
	Central Bottom	48	57	49
	Right Bottom	38	53	48
10.000	Left Bottom	49	47	34
	Central Bottom	49	57	34
	Right Bottom	47	47	34

3. INITIAL TREE ARRANGEMENT

Initial nodes that have been obtained from the calculation and classification stages before this stage become the first variable used in the tree model. FIGURE 4 shows the illustration of initial three arrangement. The initial tree is prepared by including all value components which are in the blue colour range and their nominal values. The next Leaf Node can be selected on the part that still has its nominal predictions of more than one, such as the value range 43 and range 48, then all of them must have leaf nodes. Stages for arranging leaf nodes are done one by one.

4. DETERMINING LEAF NODES

In the initial tree model that has been prepared, there is still a value component that represents more than one nominal, such as components value 43 and value 48. Therefore, it is necessary to determine the leaf node forget the next colour component (see TABEL 4) that will break down the nominal on components value 43 and value 48 are the respective nominal values range that will represent each nominal.

Tabel 4
Determined Leaf Node

R	Nominal	Total	G	Nominal	Total
38	5.000	1	**44**	1.000	1
43	1.000	1	**45**	2.000	1
44	2.000	1		5.000	1
49	2.000	1	**49**	2.000	1
59	1.000	1	**53**	5.000	1
			59	1.000	1
***Entropy*= 0**			***Entropy*= 0,33**		

5. CONVERTING MODEL TREE TO RULE

The leaf nodes that have been obtained are then inserted into the array tree, which can then, from the tree model created, be converted into arrangement rules. FIGURE 5 is the tree model of the results of the stages that have been carried out, where for components, the values 43 and 48 in blue have added additional value components for each nominal amount generated from the value components in red. From this tree, the model can be formed into a series of rules that can be used as comparative RGB data in testing using the if-then rules method. The rule (rule) obtained from the results of this decision tree calculation is as follows:

R1 IF blue 34 THEN 10.000
R2 IF blue 43 dan red 43 THEN 1.000
R3 IF blue 43 dan red 44 THEN 2.000
R4 IF blue 43 dan red 49 THEN 2.000
R5 IF blue 43 dan red 52 THEN 5.000
R6 IF blue 48 dan red 59 THEN 1.000
R7 IF blue 48 dan red 38 THEN 5. 000
R8 IF blue 49 THEN 5.000
R9 IF blue 53 THEN 1.000
R10 IF blue 56 THEN 2.000

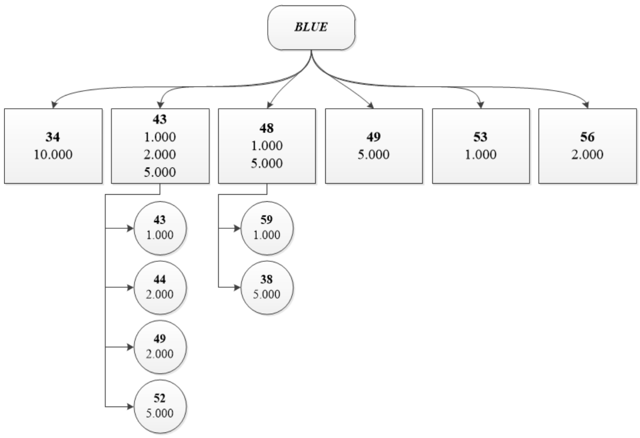

FIGURE 5. The Illustration of Tree Model

6. SIMPLIFYING RULES (PRUNING)

Of the ten rules that have been obtained, they are simplified again to four rules, where each nominal has the same colour components and has one value of that colour component. The blue colour available represents each nominal value with each different value nominally. The simplified rules are as follows:

R1 IF blue 34 THEN 10,000
R2 IF blue 49 THEN 5,000
R3 IF blue 53 THEN 1,000
R4 IF blue 56 THEN 2,000

These rules can be used as comparative data in the process of testing using the decision tree method.

III. RESULTS

A. HARDWARE DESIGN RESULTS

The hardware design that was carried out then implemented to become a mutually configurable tool. The results of this hardware design refer to the wiring diagram and schematic as well as the system design that has been created.

Table 5
Statistical Data Test

Methods	Sample	Average			Standard Deviation			Accuracy
		R	G	B	R	G	B	
Breakdown	2016	46,60	39,80	35,80	1,90	1,03	0,92	100%
	2022	36,50	33,10	30,50	0,71	0,32	3,37	90%
If-Then Rules	2016	45,60	38,10	37,40	0,52	2,18	4,58	90%
	2022	35,30	32,00	29,50	2,00	2,00	3,69	0%
Decision Tree	2016	44,20	37,50	33,70	1,23	1,08	0,82	20%
	2022	0,74	0,67	6,85	0,74	0,67	6,85	0%

Implementation of hardware design in the money nominal detection system is carried out by assembling and connecting components to one another. The Arduino nano and DF miniplayer circuits are placed at the bottom of the PCB board, while the TCS3200 colour sensor is placed at the top of the PCB board with the help of connections from the pin header so that the sensor can be placed from the top of the design. Several component parts, such as the push button, speaker, TP5100 charger module and battery, are connected using jumpers because the components need to be placed in a certain part of the box. The overall implementation of the money detection tool in Figure 5 refers to the system design, where the tool is made with a minimalist size and uses a rechargeable resource so that its use can adapt to the activities of blind people. Equipped with an on/off switch button, the use of battery power in the tool can be more efficient because the tool can be deactivated when it is not in use.

B. DATA COMPARISON METHODS RESULT

The data comparison of the three methods can be seen in FIGURE 6. Testing the nominal value of rupiah banknotes for 2016 emissions using the RGB breakdown method gets the greatest accuracy results nominal IDR 1.000 with the number of successfully detected ten times (100%). Testing by using the if-then rules method had the greatest accuracy. Nominal testing also used IDR 1.000 and IDR 100.000, with the amount detected seven times (70%). Meanwhile, the test uses the decision tree method. The greatest accuracy is found in the nominal test of IDR 1.000, IDR 5.000 and IDR 100.000, with the number detected eight times (80%).

Nominal detection testing on 2022 emission rupiah banknotes shows varying results for each method used. Results show that the highest accuracy is found in testing using the method RGB breakdown at a nominal value of IDR 2.000, where in this test, the tool can detect the nominal correctly nine times (90%). Whereas the smallest accuracy results are found in tests using the decision tree method for nominal IDR 1.000, Rp. 2.000, IDR 10.000, and IDR 50.000, wherein the tests carried out, the tool was still unable to recognize nominal money based on the RGB range owned by each nominal.

C. PRECISION TEST USING STANDARD DEVIATION

The range of values used as a reference for testing banknotes. The 2016 emissions for a nominal value of 20,000 have a range of red from 47 to 52, green range from 39 to 44, and colour range from 34 to 48. Meanwhile, the 2022 emissions for the 2022 nominal value have a red color range of 36 to 41, a green range is 33 to 37, and a blue range is 28 to 33. Banknotes did not get results detected by the tool for ten trials. This is caused by the sensor reading results showing that the range of values captured does not fall into the range of reference values, although the resulting standard deviation is still relatively low. Based on TABLE 5, the range of values produced in each experiment is dominated by values 36, 37, and 38, for red are not included in the wrong values one value as a reference. From the results of the tests carried out, the colour of the nominal amount of IDR 20,000 on the lower left side is known as the nominal money Rp. 1.000 by the device.

In the first experiment using the Breakdown method, a range of values was generated for the colours red, green, and blue, which are 37, 34, and 40, respectively, so it cannot be nominally detected by the tool. The resulting standard deviation for the blue component is quite large, so it affects the detection results obtained.

The range of values used in standard deviation testing using the if-then rules method, the value range used in this test consists of red and green with a red colour range of 32, 38, 47, 49, 55, 56, 57, 62, 66, and blue colour range 30, 35, 41, 43, 50, 52, 57. In this test, the tool can detect a nominal six times in ten experiments carried out. See the standard deviation resulting from the green and blue components. xxx

A large means that the tool's detection results are not optimal. That matters because the range of values produced during the detection process is far from the range of reference values used.

Testing on a nominal IDR 20,000 emission in 2022 has had few results detected due to the range of values produced at the time. Many tests do not fall into the reference value range. The range of values produced in each experiment is dominated by a value of 36 for red, while green is dominated by a value of 33, where the two values are not included in one of the values as a reference. From the results of the tests carried out, the colour is from a nominal value of 20,000 on

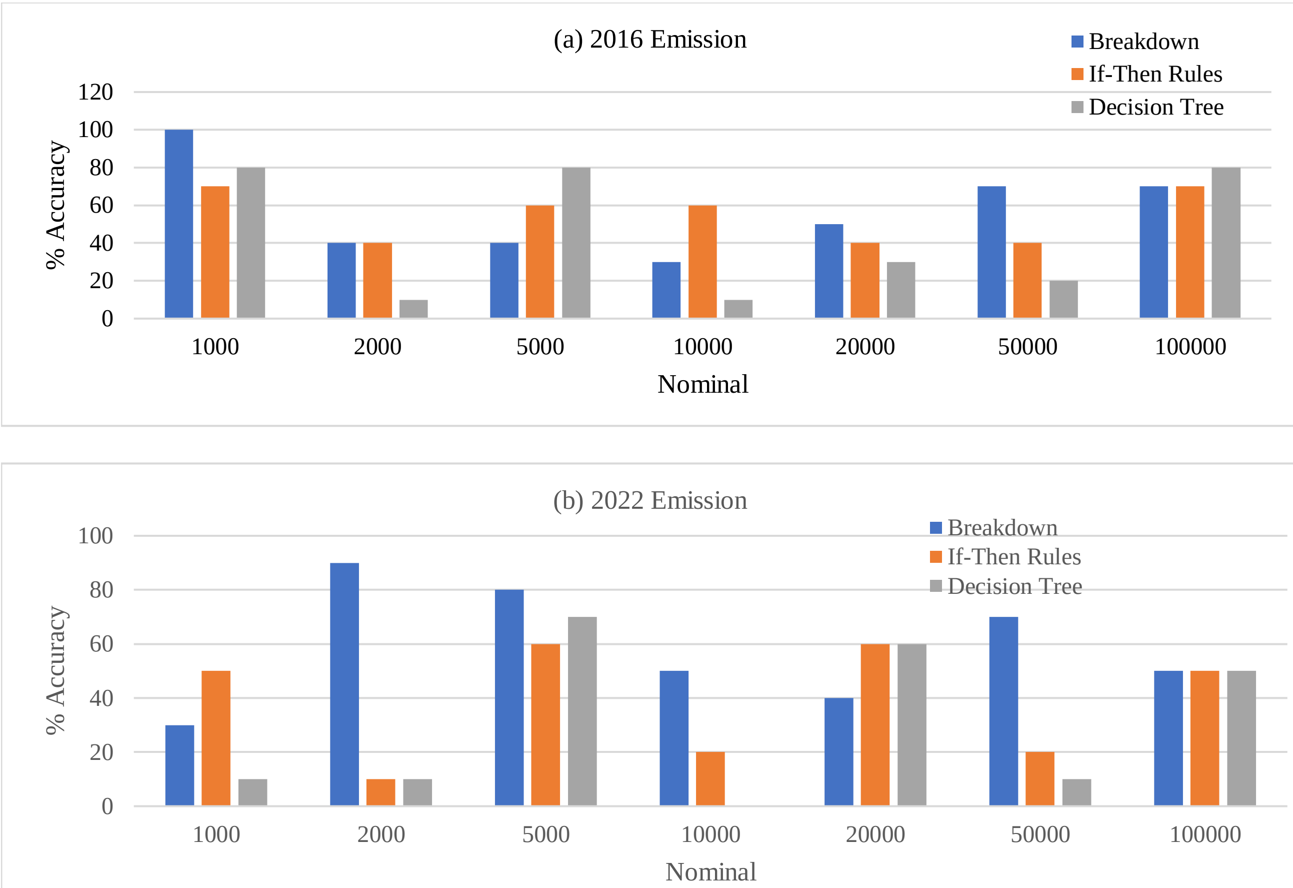

Figure 6 Data comparison of the three methods

the bottom left side is recognized as a nominal amount of Rp. 1,000 by the tool.

The range of values used in standard deviation testing with using the decision tree method at a nominal value of 20,000 applies to money paper issued in 2016 and banknotes issued in 2022. The value range used in this test only comes from red, with ranges starting from 44, 55, and 56. Testing on 2016 emission banknotes can be detected by the tool twice in ten trials done. Even though the resulting standard deviation is low, the results of the sensor readings indicate that the range of values captured is not included in the range of reference values. Based on Table 4, the range of values produced in each trial is outside the reference range, such as 43 and 45; in addition, reference values that only have one colour component also become limitations of tools in detecting nominal money.

IV. DISCUSSION

Tests were carried out using these three methods and have a relatively small average percentage of accuracy per dollar rupiah paper in both years of issuance. This is caused by several factors, such as the design of the place where the money is placed (which is small). When money is placed, it will easily shift and affect the RGB value detected. The colour sensor reading of RGB values on detected money did not match the reference RGB data or comparison RGB data, so the tool does not recognize the nominal amount of money detected. Light sensitivity also goes wrong, which is one factor that needs to be considered carefully because it can influence sensor reading results.

Compared to the other report it has been stated that the error occurred on money detector based on recognized value such RGB method is because the recognized values has the same rate with another sample[23]. Moreover, the contrast parameter also influenced to the result[24]. It has also be mentioned that gradation effect also plays role in money detector[24]. The physical condition of the money also could be the culprit leading the RGB color value overlap with each other[25]. Removing the noise is also one of the solutions that reportedly successfully solved the problem[26]. It also has been developed deep neural network based on convolution to detecting fake money[30]. The advantage of using this method is that enormous numbers of data sets could be tested. The more data has been tested, the more degree of confidence. To strengthen the function of money detector regarding its function as assistive technology. Not only the value of the money that can be recognized, but the authenticity also could be integrated to the system[27][28][29].

From the research that has been carried out, there are still areas for improvement to tackle the weaknesses in the tools. Therefore, the author provides several suggestions for development related to the tool to detect the nominal value of this banknote, including (1) Focus detection on one side of the rupiah banknote to get a better and greater level of accuracy as well. Retrieval of initial RGB data that will be used as reference data and Comparative data should be carried out at least five times to know the changes in detected RGB values to determine the use of RGB values that can represent the nominal value of banknotes rupiah. (2) An alarm can be added to the device to provide visually impaired people with information when the battery starts to run low and when the power is on, the battery is fully charged. (3) Increase the speakers' specifications so that the sound output is good. The resulting sound can be more audible when people are in a crowd. (4) The adapter currently used can only be used for charging power for 5 minutes because it easily overheats, so it has a big potential to cause damage to the device or adapter itself. (5) Widen the place to put money so that it does not shift easily when detecting.

V. CONCLUSION

It has been successfully designed the more efficient money detector for blind people using RGB method. Based on research that has been carried out regarding detection, some result has been showed the RGB breakdown method, resulting in an average accuracy percentage of 57.1% for banknote emissions in 2016 and 58.57% for banknotes issued in 2022. Using the If-Then Rules method produces an average accuracy percentage amounting to 54.28% for 2016 issue banknotes and 38.57% for banknotes emission paper in 2022. The decision tree method produces an average accuracy percentage of 44.29% for year-issued banknotes in 2016 and 30% for banknotes issued in 2022. It has been found that each side of the banknote affects the resulting accuracy by the tool because each side has different colour characteristics even though it is in one nominal value, so the accuracy of the tool is affected by the success of whether the tool can detect the nominal amount of money. To sum up the whole experiment, it can be concluded that the accuracy of the tool in detecting nominal money is found in the test results by using the RGB range breakdown method, which has the highest accuracy percentage of 100% on the 2016 issue banknotes. Meanwhile, the 2022 issue banknotes have an accuracy percentage up to 90%. For the future work, the RGB breakdown method that has been noted as the finest result could be recommended method to develop color detection and the up dated design hopefully could solve the challenge related specific place to place the bank notes on the detector.

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