Designing Image Processing-Based Banknote Identification Device for Blind People

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Abstract — **Money is a tool used all over the world to make buying and selling transactions and must reach an agreement to complete the transaction. It is certain that everyone needs money as a daily necessity, even for people with disabilities such as the blind. The limitations of blind people are problems in vision and relying on hearing for communication. The method used is a camera that detects the images contained in banknotes and sends data to the Raspberry Pi as the main controller in the system. The Raspberry Pi will process the received data signal and produce output in the form of sound. Tests carried out by calculating the success of the tool in detecting each currency. And from testing the data, it was found that the success of reading the system is almost 100% in all tests that users can use to identify banknotes.**

Keywords — Banknote identification, Blind, Money, Raspberry Pi, Voice.

I. INTRODUCTION

Money is a medium of exchange for the process of exchanging goods or services that can be accepted by society in general [1]. The buying and selling process is one of the activities carried out by the community for the welfare of their lives, including the blind [2].

The number of blind people in Indonesia is 2.4 million and continues to increase by one percent every year. What is concerning is that many visually impaired are in their productive age [3]. There is a risk of dishonesty between buyers and sellers if one of them is blind, it causes people with disabilities and blindness to suffer losses because they do not know the nominal of the banknotes [4].

Technological advances help most human activities [5]. There is a need for a tool to identify banknotes that can be used by the blind to perceive the nominal of banknotes [6]. In the future, it is important to research and develop banknote nominal detection devices [7].

Paper money in Indonesia has various denominations. Each rupiah denomination has a different size, color, design and pattern [8]. This can be a way to distinguish one nominal from another [9]. The differences in each rupiah denomination can be used as a reference for the design of the nominal identification tool for rupiah banknotes under study [10]. The banknote nominal identification system can be used by various groups in places such as self-service cashiers, bank tellers, currency exchange services, shops, hotels, and so on [11].

The process of detecting nominal banknotes uses the Red, Green, Blue (RGB) classification, then the classification uses the K-Nearest Neighbour (KNN) method [12]. The approach uses the Naïve Bayes method, but this method uses possibilities [13]. The K-Nearest Neighbour (KNN) method is the simplest and most effective method using a pattern recognition approach [14].

The recent research on the currency identification system for the blind people is using the Arduino Microcontroller, with sound as its form of output, still uses color sensors which tend to be less effective at detecting the nominal of banknotes [15].

Based on this background, the author considers that a simple identification tool is needed to help blind people to perceive the nominal of the banknotes used in transaction. There is also a need to develop the existing tool that used color sensors into using a camera system to increase the reliability of the identification tool.

II. METHOD

A. System Design

The Figure 1 is a research design that will be carried out in making the system. The first stage is literature study, tracing and studying written sources that have been made before as well as studying the needs that will be used in research. The second stage is designing *hardware* and *software*. The hardware consists of Raspberry pi 3b+ as microcontroller, Raspberry camera, a speaker, and a LED. The software used is OpenCV. The third stage is making the overall system. The fourth stage is system testing, that is carried out to test whether the system that has been made is running according to plan, but if the system testing is not appropriate then it should return to stage two, namely designing hardware and software. The fifth stage is data collection through a series of tests. The last stage is making an analysis using the data that was collected through the tests and drawing a conclusion of the best method used to develop the tool.

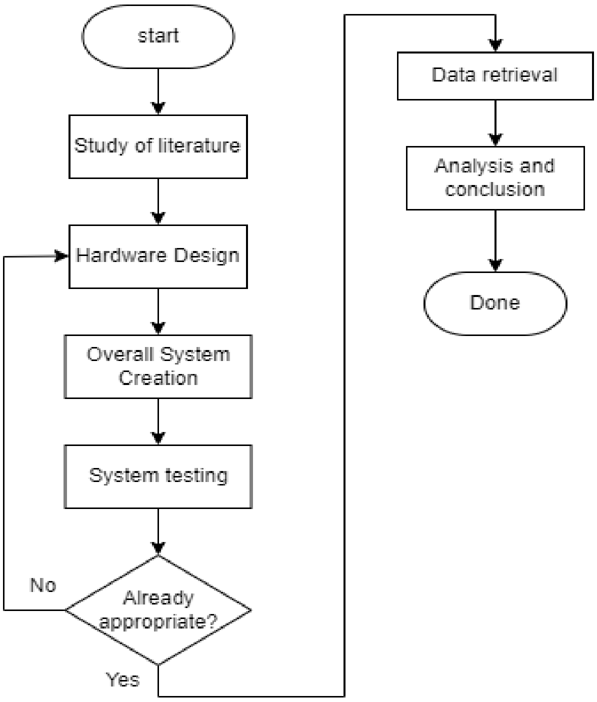

Figure 1. Research Stage Diagram

B. System Planning

Figure 2 depicts the design of the Designing Image Processing-Based Banknote Identification Device for Blind People. From the picture of Figure 2 shows a system consisting of 3 sub-systems, an input system, a process system and an output system.

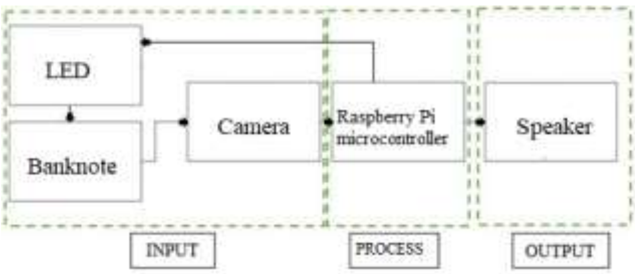

Figure 2. Block Diagram System

In the Figure 2, there are 3 parts, namely the input, process, and output. The input which consists of the camera as the main component to capture an image of a banknote illuminated by an LED. In the process, the Raspberry Pi will give the camera command to capture an image. Then the data is processed by the Raspberry PI. At the output there is a *speaker* which serve as a component to emit sound generated as a result of the identification data process.

C. Tool Work Procedure

The determination of work procedures used in the research for the title Designing Image Processing Based Banknote Identification Device for Blind People is shown in Figure 3 below and will be explained in Figure 4, Figure 5, Figure 6, and Figure 7.

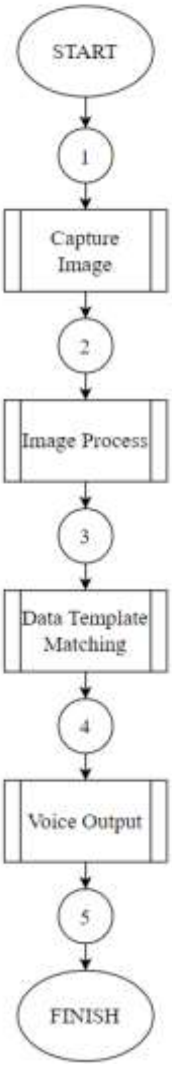

Figure 3. System Flowchart

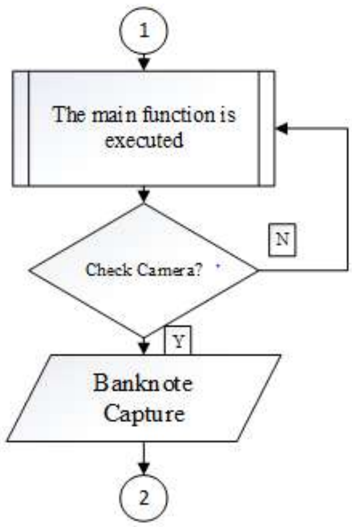

Figure 4. Capture Image Flowchart

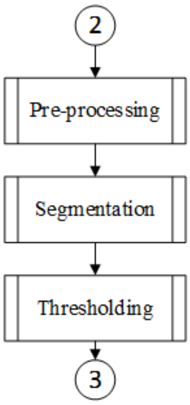

Figure 5. Image Process Flowchart

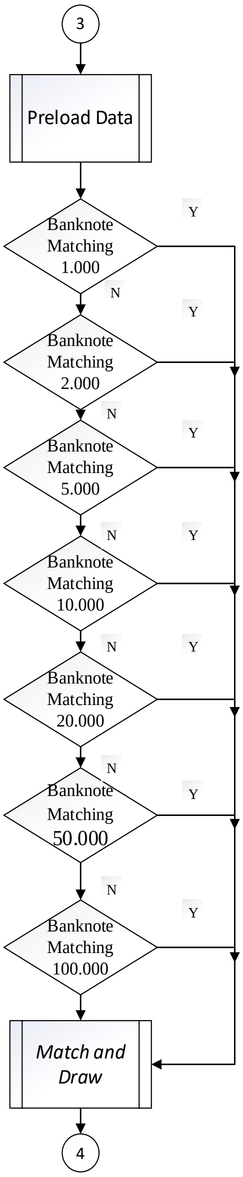

Figure 6. Data Template Process Flowchart

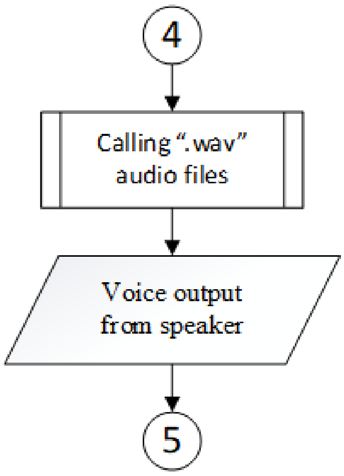

Figure 7. Voice Output Flowchart

1) *Capture Image*

The first thing to do is to run the main function. Then, check the camera connection, if it is connected, the indicator lights up, if not, the camera indicator turns off. After the camera is on, the camera can start taking image as data input.

2) *Image Process*

The pre-processing process is used to improve images and remove parts that are not needed for further processing, such as converting images to grayscale. Segmentation is a process of analysing connected image components that is used to group the intensity of each pixel to unite characters that have the same intensity. The process of repairing images that have been transformed to remove parts that are not needed for further processing.

3) *Template Data Matching*

Load the template file in the form of a picture of money that has been determined as the basis for reading money. Matches the image captured by the camera with data template money through condition selection, if it doesn't match then it will gradually match with the next data template. If the image captured by the camera matches the data template, then proceed with preparing file sound and text according to predetermined data to be prepared as output.

4) *Voice Output*

After the matching process is successful and identification results are found, the next process calls the sound file with format ".wav" that has been prepared in the process match and draw. The speaker will output sound according to the identification and sound file received as output.

D. Tool Build Planning

The following is a tool build planning of a Designing Image Processing Based Banknote Identification Device for Blind People.

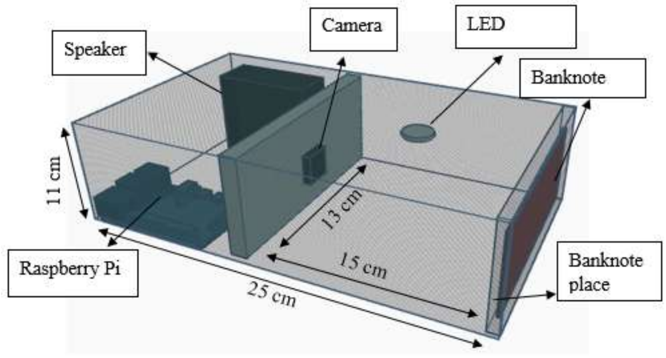

Figure 8. Tool Build Planning

In the Tool Build Planning above there are 3 parts, namely the input in which the camera is the main component to capture an image of a banknote. In the process, the Raspberry Pi will give the camera command to capture an image on a banknote. Then, the Raspberry Pi will process the data. At the output there is a speaker to emit sound generated from the data processed.

E. Electrical Build Planning

The following is an electrical build planning of a Designing Image Processing Based Banknote Identification Device for Blind People, as shown in the Figure 9.

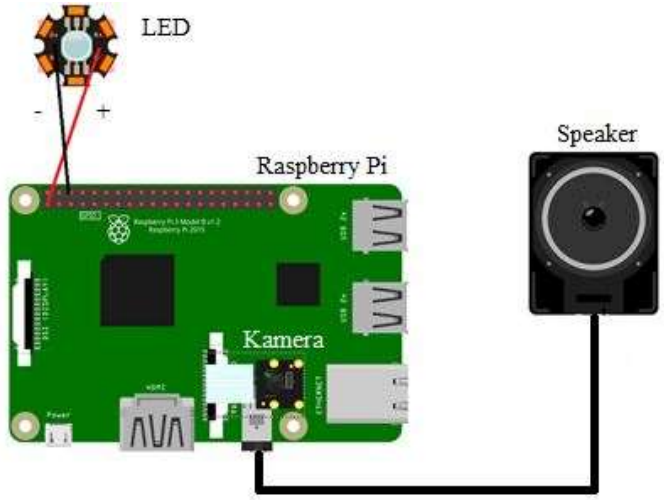

Figure 9. Electrical Build Planning

Electrical build planning is used to plan the arrangement of the electrical components of the tool.

F. System Program Planning

The following is a system program planning of a Designing Image Processing Based Banknote Identification Device for Blind People, as depicted in the Figure 10.

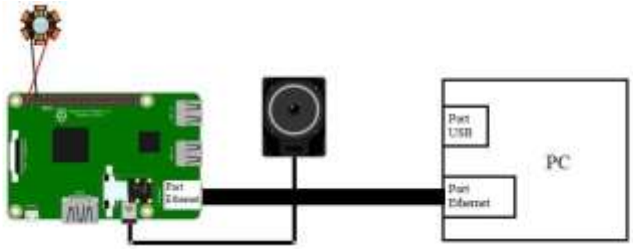

Figure 10. Connect Raspberry Pi on computer with Ethernet cable

System program planning is used to plan the arrangement components so that the tool can be controlled through a computer, as shown at Figure 11.

Figure 11. Raspberry Pi Desktop

Open the remote desktop on windows to connect computer with Raspberry Pi, as shown in Figure 12.

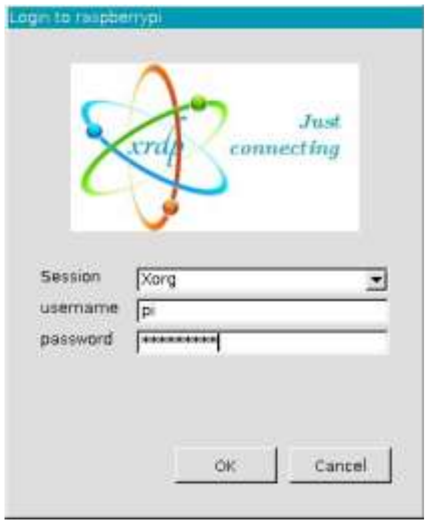

Figure 12. Log in on Raspberry Pi

Then, enter username (pi) and password (raspberry) to login into Raspberry Pi.

Figure 13. Raspberry Pi Desktop

The remote desktop view appears to enter the program on the Raspberry Pi, as depicted in Figure 13.

Figure 14. File Manager on taskbar

Open the File Manager on taskbar, as seen in the Figure 14.

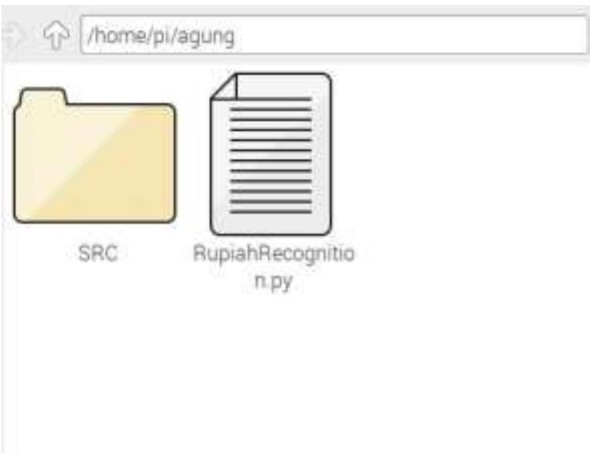

Figure 15. Program in Raspberry Pi

Then, enter the necessary programs and data into the Raspberry Pi, as depicted in the Figure 15.

Figure 16. Terminal on taskbar

Open the Terminal on taskbar, as followed in Figure 16.

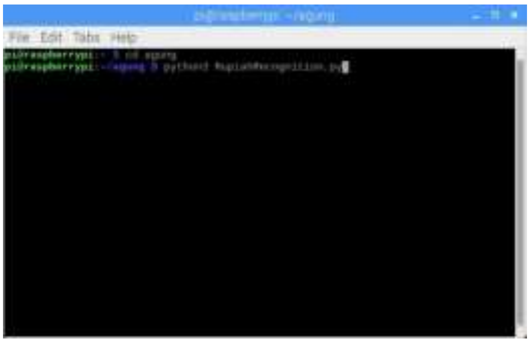

Figure 17. Raspberry Pi Desktop

Figure 17 depicts run program which is on folder, by way of entry folder Where file saved with syntax *cd* (folder name) then run the program with syntax *python3* (program name).

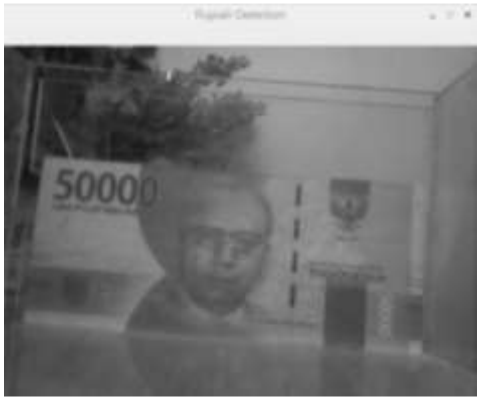

Figure 18. Camera on Raspberry Pi

The program and camera run successfully, as shown in the Figure 18 and 19. The tool that was created succeeded in detecting banknotes.

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Figure 19. Terminal on Raspberry Pi

III. RESULTS AND DISCUSSION

A. *Implementation Result*

The results of the implementation of Designing Image Processing Based Banknote Identification Device for Blind People are shown in Figure 13 and Figure 14. The Raspberry Pi will give the camera command to capture an image on the banknote which has been illuminated by the LED. Then the data is processed by the Raspberry Pi as a data processor. At the output there is a speaker that functions as a component to produce sound generated from the identification data process.

Figure 20. Top View

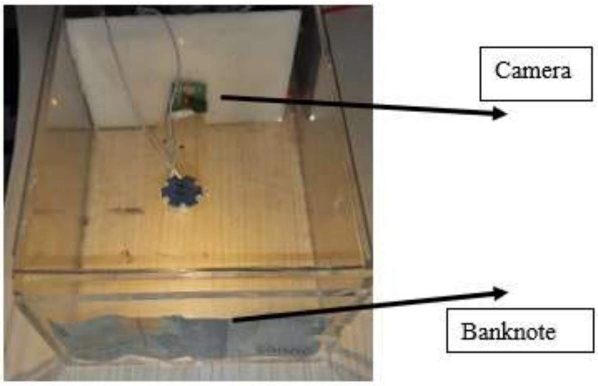

Figure 21. Front View

B. *Test Result*

In this test, a comparison of 3 methods was carried out to find the results of *query instance* (sample point) newly classified based on the majority of the processing category when calculating in the value lookup equation *distance*. Figure 15 is sample data captured by the camera, while Figure 16 is reference data which will later be equated with sample data or captured banknotes by the camera, as shown in the Figure 22 and 23.

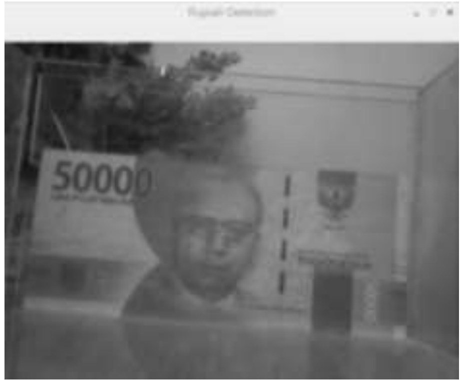

Figure 22. Captured Camera

Figure 23. System Flowchart

Table I shows the results of Authenticity Detection Test Results with algorithms Euclidean.

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TABLE I
AUTHENTICITY DETECTION TEST RESULTS WITH ALGORITHM EUCLIDEAN

No.	Nominal	Number of Samples	Correct Test Result
1.	1.000	10	10
2.	2.000	10	9
3.	5.000	10	9
4.	10.000	10	10
5.	20.000	10	9
6.	50.000	10	10
7.	100.000	10	10

From Table I above we can see that from the average computation time, there are two test data that are too bright so that they affect other images (binary), and when the two features are added together the total distance obtained will be further away from the actual money test data.

Table II shows the results of Authenticity Detection Test Results with algorithms *Manhattan.*

TABLE II
AUTHENTICITY DETECTION TEST RESULTS WITH ALGORITHM *MANHATTAN*

No.	Nominal	Number of Samples	Correct Test Result
1.	1.000	10	7
2.	2.000	10	7
3.	5.000	10	9
4.	10.000	10	9
5.	20.000	10	8
6.	50.000	10	9
7.	100.000	10	8

From Table II above we can see that nominal Rp. 5,000, Rp. 50,000, and Rp. 100,000 on the algorithm *Manhattan* it has perfect accuracy on all sample quantities.

Table III shows the results of Authenticity Detection Test Results with algorithms *Chebychev.*

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TABLE III
AUTHENTICITY DETECTION TEST RESULTS WITH ALGORITHM *CHEBYCHEV*

No.	Nominal	Number of Samples	Correct Test Result
1.	1.000	10	9
2.	2.000	10	7
3.	5.000	10	9
4.	10.000	10	8
5.	20.000	10	7
6.	50.000	10	9
7.	100.000	10	9

From Table III above we can see that the true test results are quite high, but nothing shows the true test results on all samples on currency values.

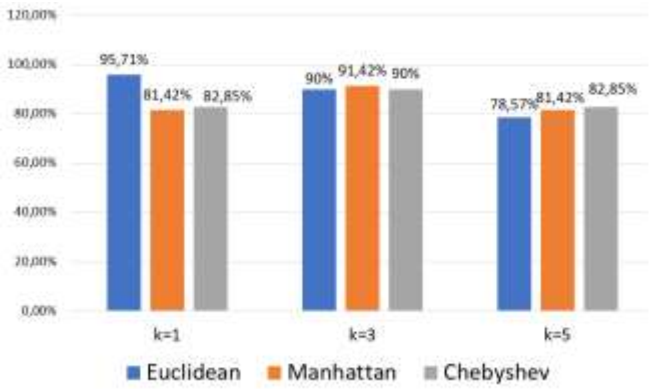

Figure 24. Comparison of the 3 methods

Based on Figure 24, the highest accuracy is shown by k=1 using Euclidean algorithm with accuracy rate at 95,71% with the lowest accuracy is shown by k=5 using Chebyshev algorithm with accuracy rate at 73,21%. Hence why this study uses Euclidean algorithm with k=1.

In order to make sure that the tool developed in this study have the most accurate results, the author decided to determine the most suitable brightness factor level between 1.45, 1.55, 1.65, and 1.75. The following table shows the accuracy rate between the various brightness factor levels.

TABLE IV
COMPARISON OF ACCURACY WITH DIFFERENT BF VALUES

No.	BF value	Accuracy
1	1,45	80%
2	1,55	84,24%
3	1,65	87,14%
4	1,75	81,42%

From Table IV the accuracy comparison above, it can be concluded that the highest accuracy is in the value *brightness factor* 1.65, which is equal to 87.14%. This is because in this BF condition the noise that is processed until the nominal detection process is less than BF in other conditions. In the table it can be seen that there has been an increase and decrease in the accuracy value, peaking at BF = 1.65 and dropping again at BF = 1.75. Whereas in the condition BF = 1.75 the noise is indeed less, but there are some missing features in the processed image.

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Figure 25. Comparison of BF at a nominal value of Rp. 100,000

This is due to the incompatibility of the algorithm *pre-processing* nominal detection of several money images that have different characteristics from the characteristics defined in the pre-processing algorithm. The reflected light intensity in each money image from the LED light source varies, making one image different from another, and has an effect on the contamination of the color and brightness captured by the camera.

Table V shows the results of nominal detection testing using BF = 1.65. The brightness factor level was chosen because it got the best accuracy test result, which is at 87.14%.

TABLE V
NOMINAL DETECTION TEST WITH BF = 1.65

No.	Nominal	Number of Samples	Correct Test Result	False Test Result	Percentage
1.	1.000	10	9	1	90%
2.	2.000	10	8	2	80%
3.	5.000	10	9	1	90%
4.	10.000	10	10	0	100%
5.	20.000	10	7	3	70%
6.	50.000	10	8	2	80%
7.	100.000	10	10	0	100%
	Total	70	61	9	87,14%

From the results of the nominal detection test in Table V it can be concluded that the nominal Rp. 10,000 and Rp. 100,000 in testing conditions with a brightness factor of 1.65 gets the best results with an accuracy value of 100%. Meanwhile, for other nominal results, the accuracy is around 70% and above. So, when all the data is added up, the total accuracy of the nominal detection for BF = 1.65 is 87.14%.

Table VI shows the results of total computational time of banknote identification.

TABLE VI
TOTAL COMPUTING TIME OF BANKNOTE DETECTION

No.	Nominal	Number of Samples	Computing Time (s)
1.	1.000	10	1,51
2.	2.000	10	1,61
3.	5.000	10	1,75
4.	10.000	10	1,85
5.	20.000	10	2,04
6.	50.000	10	2,09
7.	100.000	10	1,97

From Table VI above we can see that from the average computation time, it turns out that the processing time (detection nominal) at a nominal Rp.100,000 is relatively faster, because this nominal initial processing stage mostly does not require too many iterations. On the other hand, at a nominal value of Rp. 20,000, the average computation time obtained is longer, because there are too many iterations of the initial processing at that nominal. Most of the detection errors at this nominal are because the system does not get the binary image data it wants to compare with the reference data, so it runs too many iterations.

IV. CONCLUSION

This study aimed to develop a tool that can help blind people to identify nominal of banknotes using a camera system with a voice output. Various methods were compared in the process of this study to obtain a tool with the highest speed and accuracy. The tool designed through this study improve the reliability, accuracy, and speed in identifying the nominal of banknotes, compared to previous studies. A development can be made through adding references to the nominal reference data from banknotes in various conditions to maximize the ability of the tool in identifying nominal of the banknotes regardless of the conditions.

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