IoT-based banknotes saving automation system

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ABSTRACT

Many problems occur with traditional savings, such as users not knowing the nominal amount that has been saved later, and the authenticity of the money saved. To overcome this problem, the "Savings Storage Automation System with IoT-Based Banknotes" tool was created, this tool aims to help users save money easily and safely. The system design is based on Arduino Mega. The inputs on the Arduino Mega consist of a GY-33 TCS34725 as a color sensor and a keypad to perform functions. The output produced is in the form of nominal data of banknotes that can be seen by the user through an LCD and sent to a database, checking the authenticity of the money is done manually by using ultraviolet. The method used to identify the nominal banknotes is based on the reading of each RGB value and color temperature on each nominal banknote. The average accuracy of reading currency values on real banknotes reaches 88%, while in testing counterfeit banknotes it is 14%. Testing execution time when entering money into savings is 3.57 seconds and data to the database is 6.57 seconds.

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1. INTRODUCTION

Money is something that is accepted by the public as a medium of exchange in economic activity. Money is accepted as a means of payment for buying and selling transactions for goods and services, as well as wealth or other valuable assets, and also as a means of paying debts [1]. Saving is one of many ways of managing finances that aims to save reserve funds in the future. The main purpose of saving is to claim financial stability if things happen that are not desirable in the future. Indirectly, saving can help to know about priorities in finance. One of the ways to save money traditionally is by inserting the money to the piggy bank periodically and collecting the money in the future with a hammer [2]. Saving traditionally is not effective in today's era. In addition to not being able to see the amount of money that has been saved, saving traditionally is also at risk of the possibility of entering counterfeit money and damage to savings tools because the materials from traditional savings materials are easily damaged [3]. One of the solutions to overcome this problem is to use a smart saving system [4] [5].

Based on the problems above, a savings storage automation system with the internet of things-based banknotes is designed that will help the public to be able to save more easily and safely. Color sensor GY-33 TCS34725 is used to identify banknotes that will go into savings and nominal calculations will be displayed on LCD 16x2 I2C and sent to the database by using ESP32 as a Wi-Fi module [6]. The security system design is using a solenoid door lock to secure access to banknotes and a 4x4 keypad to open the solenoid door lock and enter the banknote reading function to make it easier for users to save more easily and safely.

2. THEORETICAL BASIS

2.1. Internet of Things

The Internet of things (IoT) is a concept that aims to expand the benefits of continuously connected internet connectivity. With the development of the Internet of Things (IoT), this technology can be used in learning and practical activities [7]. Currently, human interaction with the internet is growing rapidly, and there are many changes to human workflow that are much easier thanks to the help of the internet [8]. The development of the Internet of Things (IoT) in human life greatly helps daily activities, with the advent of IoT, humans can easily control and access anything remotely [9].

An example of the internet of things (IoT) that is often encountered is a concept called a smart home. This smart home idea helps daily human activities, for example, opening automatic house doors with just a fingerprint, opening automatic gates through smartphones, and turning on lights or other electricity at home with only smartphones [10].

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2.2. Banknotes

Money is a generally accepted medium of exchange that can be exchanged for goods or services [11]. One type of money is a banknote. Central banks or governments create paper money. In Indonesia, banknotes are made by Bank Indonesia in Rupiah currency. Rupiah banknotes consist of several nominal denominations and different colors which will later be detected by the color sensor based on the RGB value of each nominal. Rp.1000 is dominant in yellow and gray, Rp.2000 is dominant in gray, Rp.5000 is dominant in brown, Rp.10000 is dominant in purple, Rp.20000 is dominant in green, Rp.50000 is dominant in blue, and Rp.100000 is dominant in red [12]. To detect the colors, this paper uses RGB values and color temperature.

RGB (Red, Green, and blue) is an additive color naming based on the color's red, green, and blue [13]. These colors are usually used as a base color to produce new colors, by combining the percentage of red combined with the percentage of green and combined with the percentage of blue to produce a new, different color, the number of color combinations in the RGB value reaches tens of millions of color types.

Color Temperature is the temperature at the visible color characteristics of the light source, the color temperature is usually used to measure the color of the incoming light source by radiation from the black body locus, such as a color temperature of more than 6,000K is referred to as cold color (bluish white). Lower temperatures (1,500 – 3,500) are referred to as warm colors (reddish/yellowish white) [14].

2.3. Firebase

Firebase is one of Google's NoSQL-based service databases that can help developers develop their applications, by using Firebase developers don't have to spend a lot of effort on backend problems [15]. The Firebase service that is used in this paper is Firebase Realtime Database. Firebase Realtime Database is a database service that is hosted via the cloud. The data to be sent will be stored in JSON form and synchronized in real-time with users connected to mobile or web applications.

3. METHOD

The aim of this IoT-based banknote storage system is for recording the amount of savings, the authenticity of the banknotes, and the nominal value of banknotes automatically into the mobile application. This tool is based on Arduino Mega which consists of several components, namely Arduino Mega, NodeMCU, GY-33 TCS34725, Keypad Pin 4x4, LCD 16x2, Selenoid Door Lock, UV High Power LED, Servo Motor MG90S.

The input of this tool is Arduino Mega which functions to regulate the main operating system for data processing, GY-33 TCS34725 color sensor which functions to identify colors on different banknote nominals, UV High Power LED as an ultraviolet light emitter which serves to identify the watermark on money. Keypad Pin 4x4 functions as an input for selecting solenoid door lock unlock and enters the color sensor reading function, Selenoid door lock functions as a door lock at the top of the savings account for access and securing the banknotes, and the power supply serves to provide DC voltage to the Arduino Mega. While the output section is a 16x2 LCD that functions to display nominal information on the money entered, the MG90S Servo Motor serves to push/drop money into savings, and NodeMCU connects Arduino Mega to the internet to send data information on the amount of savings into the mobile application via Firebase.

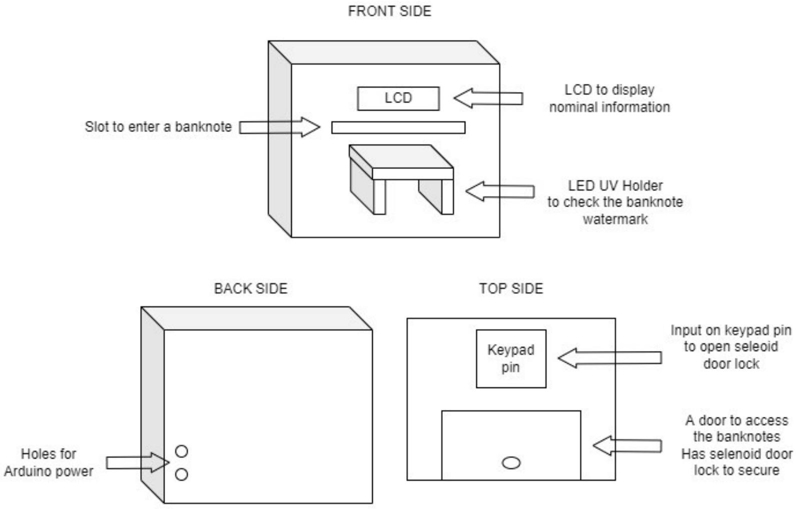

Figure 1. Saving Case Illustration

Figure 1 shows an illustration of a saving case as the initial design for a saving case with a material made of wood.

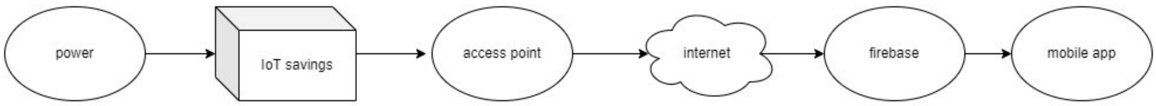

Figure 2. System Design

Figure 2 shows an illustration of the system design starting from the power until the data is sent to the database.

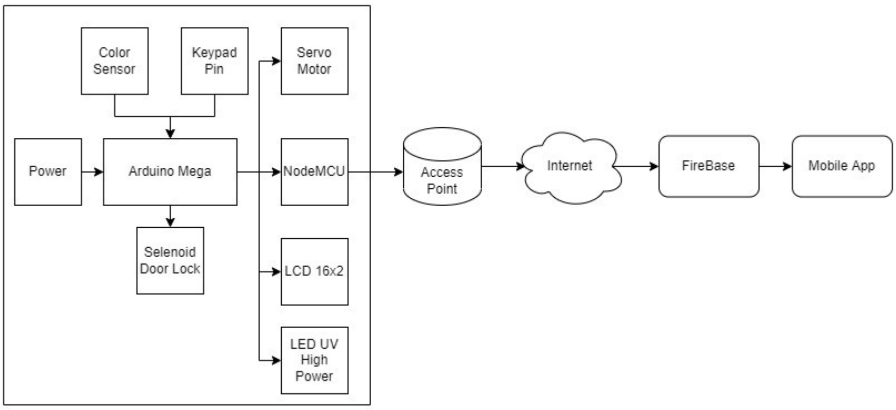

Figure 3. Block Diagram

The block diagram shown in figure 3 in this paper consist of several components. On the transmission side, there are Arduino Mega, NodeMCU, GY-33 TCS34725 color sensor, MG90S Servo Motor, 16x2 LCD, high power UV LED, and Access Point. Meanwhile, from the receiving side, there are FireBase and Mobile Applications.

The hardware design in this final project is to create an IoT-based savings account based on Arduino Mega as the sender while Firebase and mobile applications become the receiver. Therefore, the input to the hardware consists of Arduino Mega as a microcontroller, NodeMCU as an Arduino link to the internet, GY-33 TCS34725 as a color sensor, UV High Power LED as an ultraviolet light transmitter, Servo Motor MG90S as a motor for pushing banknotes into the system. savings, Keypad Pin 4x4 as a switch to open the selenoid door lock by entering the pin and entering the banknote reading function, Selenoid door lock, LCD 16x2 as output information data or user interface on the hardware. This design is illustrated in Figure 4.

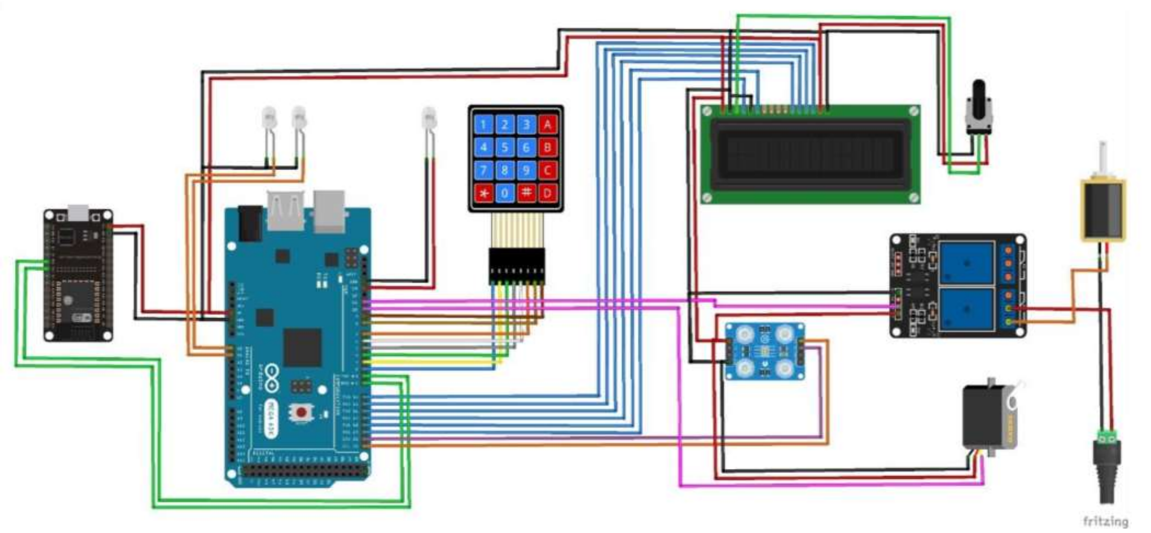

Figure 4. Hardware Design

Figure 5 shows the flow of the savings operation with a color sensor as input to produce output in the form of a nominal number of banknotes on a 16x2 LCD. If the color sensor reads the nominal of the banknote, the servo motor will move to drop the banknote into the savings.

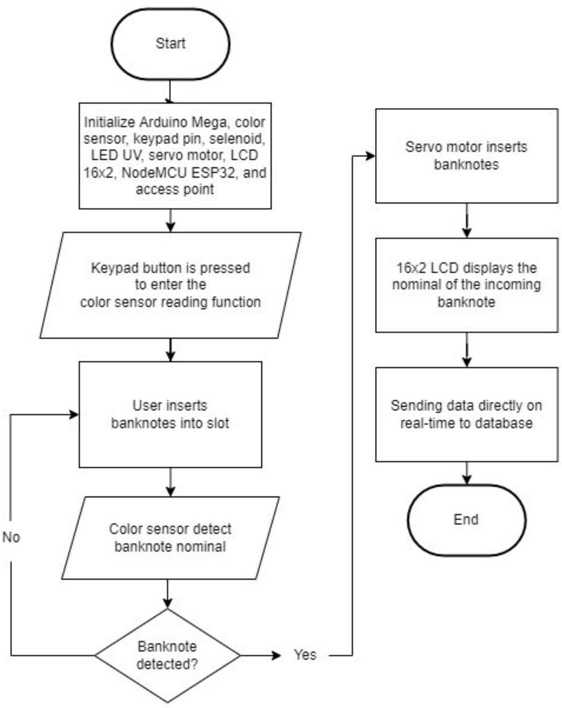

Figure 5. Banknote Operation Flow

Figure 6 shows the flow of the banknote collection system in the savings account, registering a pin to unlock the selenoid door lock and then entering the registered pin, if the pin entered is correct then the solenoid door lock will automatically unlock, and banknotes can be retrieved.

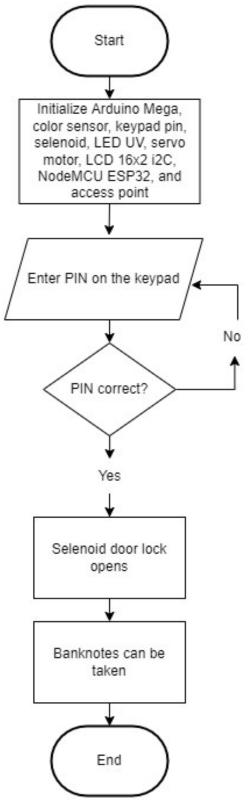

Figure 6. Banknote Collection Flowchart

Data processing is done by receiving all data first from the color sensor in the form of nominal and color on banknotes, then all the data is stored in json format using the json.set() function and sent using the Firebase.pushJSON() function so that the data transmission is more structured. with the FirebaseESP32 library, data is sent to the Firebase real-time database. This flow is pictured in figure 7.

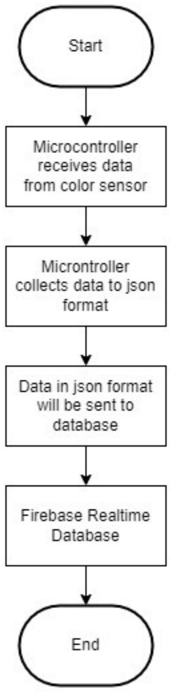

Figure 7. Data Processing Flowchart

4. RESULTS AND DISCUSSION

4.1. Red, Green, and Blue Value Test

To identify the nominal value of banknotes, it is necessary to test the values of red, green, and blue so that the system can read each nominal on banknotes. The test was carried out 10 times taking values on 5 banknotes for each nominal, such as nominal Rp5,000, nominal Rp10,000, nominal Rp20,000, nominal Rp50,000, and nominal Rp100,000. These results can be seen in Table 1.

Table 1. RGB Value Tests

Nominals	Red		Green		Blue	
	Min	Max	Min	Max	Min	Max
Rp5,000	210	250	310	370	330	390
Rp10,000	180	215	300	345	395	455
Rp20,000	180	220	340	390	375	435
Rp50,000	170	210	320	370	420	485
Rp100,000	195	240	295	340	345	415

The red, green, and blue values for these nominals' values have almost the same value, this value ranges from 210 – 485.

4.2. Color Temperature Test

Taking red, green, and blue values for each banknote nominal has almost the same value, to avoid errors in sending nominal banknote data, color temperature data is taken. The distance between the color temperature values for each banknote is quite different, to increase the accuracy of the reading on the banknote nominal, the color temperature value is quite accurate to add. Test data can be seen in Table 2 with nominal 5,000, nominal 10,000, nominal 20,000, nominal 50,000, and nominal 100,000.

Table 2. Color Temperature Tests

Nominals	Color Temperature	
	Min	Max
Rp5,000	7100	7400
Rp10,000	9450	9900
Rp20,000	8900	9300
Rp50,000	10400	11200
Rp100,000	7900	8100

4.3. Different Light Conditions Test

The test was carried out by measuring lux or different light conditions, such as indoors with no light conditions (lux 3), indoors with light conditions (lux 32), and outdoors with sunlight (lux 1354). This test aims to measure whether the savings can be used in different light conditions. If the experiment is successful, the banknote will be read by the color sensor and if the experiment fails, the banknote will not be read by the color sensor. The tests are shown in Table 3.

Table 3. Different Light Conditions Test

Light Condition	Nominals				
	Rp5,000	Rp10,000	Rp20,000	Rp50,000	Rp100,000
No Light (lux 3)	Success	Success	Success	Success	Success
With Light (lux 32)	Success	Success	Success	Success	Success
Sunlight (lux 1354)	Success	Success	Success	Success	Success

4.4. Color Accuracy Test on Real Banknotes

In this test, color accuracy was tested with different currency conditions on each nominal banknote such as the condition of the old banknotes and the condition of the new banknotes randomly 10 times. The condition of the banknotes used is still in circulation and is suitable for use. This test aims to measure the accuracy of the color sensor in reading the values of r, g, b, and color temperature for each of 39 different banknotes. The tests carried out on nominal banknotes are shown in Table 4.

Table 4. Color Accuracy Test on Real Banknotes

Attempt #	Rp100,000	Rp50,000	Rp20,000	Rp10,000	Rp5,000
1	Success	Success	Success	Success	Success
2	Success	Success	Success	Success	Success
3	Success	Success	Success	Success	Success
4	Success	Success	Success	Fail	Success

Attempt #	Rp100,000	Rp50,000	Rp20,000	Rp10,000	Rp5,000
5	Success	Success	Success	Fail	Success
6	Fail	Success	Success	Success	Success
7	Success	Success	Success	Success	Fail
8	Success	Success	Success	Success	Success
9	Success	Success	Fail	Success	Success
10	Success	Fail	Success	Success	Success

The table above shows the results of the accuracy of testing the color sensor readings on banknotes, in a total of 50 trials, which were successfully read, namely 44 times, and those that were not successfully read 6 times. The final accuracy result shows 88% accuracy.

4.5. Color Accuracy Test on Counterfeit Banknotes

In this test, the aim is to measure the accuracy of the color sensor in reading the values of r, g, b, and color temperature on counterfeit banknotes. The tests carried out on the nominal banknotes are shown in Table 5 below.

Table 5. Color Accuracy Test on Counterfeit Banknotes

Attempt #	Rp100,000	Rp50,000	Rp20,000	Rp10,000	Rp5,000
1	Fail	Success	Fail	Fail	Fail
2	Fail	Fail	Fail	Fail	Fail
3	Fail	Fail	Fail	Fail	Success
4	Fail	Success	Fail	Fail	Fail
5	Fail	Fail	Fail	Fail	Success
6	Fail	Success	Fail	Fail	Fail
7	Fail	Success	Fail	Fail	Fail
8	Fail	Fail	Fail	Fail	Fail
9	Fail	Fail	Fail	Fail	Fail
10	Fail	Fail	Fail	Success	Fail

The table above shows the results of the accuracy of the color sensor reading of counterfeit banknotes, in a total of 50 trials, 7 were successful, and 43 were unsuccessful. The accuracy results obtained are 14% accurate.

4.6. Execution Time Test

This test aims to see how long the delay is needed to receive incoming money, be read, to send data into the database. This test is carried out by recording the time when entering banknotes into savings and also sending data to the database. Here are the results of the time test when putting banknotes into savings.

Table 6. Execution Time Test

Banknotes go to:	Time (second) / Nominals					Average (second)
	Rp100,000	Rp50,000	Rp20,000	Rp10,000	Rp5,000	
Savings	3.53	3.51	3.56	3.72	3.55	**3.57**
Database	6.12	6.35	6.52	7.08	6.7	**6.56**

In testing the amount of execution time in Table 6, the average time results obtained are 3.57 seconds when banknotes enter the savings account, and 6.56 seconds when banknote data enters the database.

5. CONCLUSION

Based on the research and design in the Final Project that has been carried out, the following conclusions can be drawn: The system can be successfully made according to the design. In the accuracy test, an accuracy value of 88% was obtained for reading original banknotes and readings on counterfeit banknotes with an accuracy value of 14%. The average execution time obtained from putting money into savings until it is read is 3.57 seconds. The processing time to send data to the database is 6.56 seconds.

Some suggestions that can be used to develop the system in this Final Project are as follows: 1. It takes a special material to increase the level of durability of the tool, 2. It takes a special place to separate each nominal banknote that comes in so that it is neatly arranged, 3. Placement of the entry position of banknotes for more precision, and lastly, 4. Identify the authenticity of banknotes automatically.

REFERENCES

[1] Y. R Nasution, “Alat pengenal nominal uang untuk tunanetra menggunakan sensor warna dan ultraviolet,” *JISTech*, vol. 4, no. 1, 2019.
[2] S. Donovan, *Budgeting*. Minneapolis: Lerner Publications Co., 2006.

[3] D. Lestari and A. M. Ferlina Trenggana, “Pengaruh literasi keuangan terhadap minat menabung (studi pada siswa SMA di Kota Bandung),” *Telkom Univ*., 2017, Accessed: Jul. 12, 2022. [Online]. Available: www.ojk.go.id.

[4] Y.-J. Lee, K. S. Kim, and H.-J. Lee, “Smart piggy bank: in-home banking system for children: demo abstract,” in *Proceedings of the Second International Conference on Internet-of-Things Design and Implementation, New York, NY, USA, Apr. 2017*, pp. 293–294. doi: 10.1145/3054977.3057318.

[5] B. L. Wee and Y. W. Eng, “IoT piggy bank for money saving habit instillation”, *JITA*, vol. 9, no. 1, pp. 1-10, 2021.

[6] B. R. Samalo, H. Gunawan, and A. Wibowo, “Alat pemilah uang kertas berdasarkan nilai pecahan dengan menggunakan sensor warna TCS230,” *Widya Tek*., vol. 8, no. 1, pp. 23–33, 2017, doi: 10.33508/WT.V8I1.1284.

[7] D. Prihatmoko, “Penerapan Internet Of Things (IoT) dalam pembelajaran di UNISNU Jepara,” *Simetris J. Tek. Mesin, Elektro dan Ilmu Komput*., vol. 7, no. 2, pp. 567–574, 2016, doi: 10.24176/SIMET.V7I2.769.

[8] E. M. Rizki, S. M. Nasution and A. L. Prasasti, "Design of laundry box as supporting smart laundry system based on internet of things," *2020 International Conference on Information Technology Systems and Innovation (ICITSI)*, Bandung, Indonesia, 2020, pp. 398-404, doi: 10.1109/ICITSI50517.2020.9264946.

[9] I. D. J. Burdadi, R. Ridwan, and I. Nugraha, “Aplikasi sensor warna Tcs3200 pada sistem penyortiran barang berbasis internet of things (IoT),” *Pros. Semin. Nas. Inov. Teknol. Terap. Apl*., pp. 141– 145, 2022, Accessed: Jul. 13, 2022. [Online]. Available: https://snitt.polman-babel.ac.id/index.php/snitt/article/view/173.

[10] Y. Jie, J. Y. Pei, L. Jun, G. Yun, and X. Wei, “Smart home system based on IOT technologies,” *Proc. - 2013 Int. Conf. Comput. Inf. Sci. ICCIS 2013*, pp. 1789–1791, 2013, doi: 10.1109/ICCIS.2013.468.

[11] F. S. Mishkin, *Ekonomi Uang, Perbankan, dan Pasar Keuangan Buku 1*. Jakarta, Indonesia: Salemba Empat, 2008

[12] R. Ramadhan, J. Y. Sari, and I. P. Ningrum. “Identification of authenticity and nominal value of Indonesia banknotes using fuzzy K-nearest neighbor method”. *International Journal of New Media Technology*, vol. 6, no. 1, pp. 32-37. 2019.

[13] S. H. Chae, J. K. Kim, and S. B. Pan. “A study on the Korean banknote recognition using RGB and UV information”. In: Ślęzak, D., Kim, Th., Chang, A.CC., Vasilakos, T., Li, M., Sakurai, K. (eds) Communication and Networking. FGCN 2009. *Communications in Computer and Information Science*, vol 56. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-10844-0_55

[14] D. Durmus. "Correlated color temperature: Use and limitations." *Lighting Research & Technology*, 2021.

[15] W. J. Li, C. Yen, Y. S. Lin, S. C. Tung, and S. Huang. “Just IoT internet of things based on the Firebase real-time database”. *In 2018 IEEE International Conference on Smart Manufacturing, Industrial & Logistics Engineering (SMILE),* pp. 43-47, 2018.