



IoT Based Water Turbidity Classification Using Color Sensor TCS3200

Ida Ayu Vigi Meidhyana Putri¹, Wirarama Wedashwara¹(✉) , Ariyan Zubaidi¹ ,
and I Wayan Agus Arimbawa²

¹ Department of Informatics Engineering, University of Mataram, Mataram, Indonesia
idaayuvigi03@gmail.com, {wirarama, zubaidi13}@unram.ac.id

² Department of Technology Management, Economic, and Policy, Seoul National University,
Seoul, Republic of Korea
arimbawa@snu.ac.kr

Abstract. The use of water in households must pay attention to the cleanliness factor of the condition of the water itself. Based on the Regulation of the Minister of Health of the Republic of Indonesia Number 416/Menkes/PER/IX/1990, water quality requirements include physical, chemical, biological, and radiological qualities so that if consumed or used, it will not cause side effects. This study created a water turbidity classification system based on the TCS3200 IoT color sensor using the MQTT data communication protocol. This research was conducted by testing three times, namely, black box testing, then hardware testing, namely testing the TCS3200 color sensor, and testing with different containers. This study's classification system belongs to the excellent system category and is feasible to use. The classification system website page can display data from current water conditions and detection history obtained using the MQTT protocol. Based on black box testing, it can be concluded that all functions have been running properly, and the system can perform classification well. Experiments using different containers show that the system can perform the classification as expected if it is calibrated first on each container. Based on the graph of RGB values, mud, moss, and soil have relative RGB values. Tests carried out with closed containers can produce a better classification than containers with open conditions because light intensity influences the surroundings.

Keywords: Internet of Things · Smart Electrical Vehicle · Genetic Programming First Section

1 Introduction

Water is one of the most important sources of life. As the population increases, the use of water by the community for various daily needs such as drinking, cooking, washing clothes, bathing, washing toilets (MCK), and so on is also increasing. The use of water in households must pay attention to the cleanliness factor of the condition of the water itself. Clean water is water that meets the requirements. Based on the Regulation of the Minister of Health of the Republic of Indonesia Number 416/Menkes/PER/IX/1990, water quality

requirements include physical, chemical, biological, and radiological qualities so that if consumed or used, it will not cause side effects [1].

Water used for household needs is distributed through connected pipes from wells and PDAMs with the pipes embedded in the ground. However, the quality of the water can decrease due to several factors. Decreasing water quality in households can occur due to earthquakes, environmental factors (One example is if the water source comes from limestone hills, the lime content in the water will be high [2]), and pipe leaks, resulting in water, can be contaminated. These factors cause the water to be used can contain high levels of mud, moss, soil, and lime.

From these problems, one way that can done so that people know the quality of the water to be used is polluted or not is to look at the physical condition of the water based on its turbidity. Turbidity is a condition in which a liquid's transparency decreases due to insoluble substances' presence. Turbidity is a solution's optical property that causes light to be absorbed and refracted [3]. Water will be said to be cloudy if the water contains so many suspended particles of material that it gives a muddy and dirty color or appearance. Materials that cause turbidity include soil, silt, moss, and high lime [4].

The rapid development of technology today has significantly increased efforts to ease humans' workload as implementing subjects. One of these technologies is the Internet of Things (IoT). IoT is a network contained in physical devices, vehicles, household appliances, and other items equipped with electronic systems, software, sensors, actuators, and connectivity that allow the exchange of data [5]. By using IoT technology, it can help the community to detect water quality based on the color of its turbidity. For light, the constituent colors are red (Red), green (Green), and blue (Blue), better known as RGB [6]. The color parameters have different light waves. Therefore, a sensor that is sensitive to color changes in the basic color is needed by using the TCS3200 color sensor. Using the TCS3200 color sensor will produce RGB output that can be used to see the cause of water turbidity in households, whether it is caused by soil, mud, moss, or high lime content. However, the RGB output generated from the TCS3200 color sensor may differ depending on the base color used in household plumbing. Therefore, if the basic color used changes, it is necessary to re-calibrate the color to get an accurate RGB output in classifying the causes of water turbidity.

Based on what has been described above, in this study, the author will design a system that can classify water turbidity in households based on the Internet of Things color sensor TCS3200 using Message Queuing Telemetry Transport (MQTT) data communication. The MQTT protocol is lightweight because it sends messages with a small header of 2 bytes and works using the publish/subscribe concept [7]. The MQTT protocol was chosen because it is related to using the protocol in a system that uses digital sensors. The MQTT protocol is stated to be appropriate and appropriate [8]. This system uses a website to display the classification results. With the color sensor, TCS3200 is a publisher that sends data using the MQTT protocol over the network to an active broker on a laptop device, and the broker will send the data to a website that subscribers can access. It is hoped that this research can help the community to find out whether the water to be used is polluted or not, and if the water is detected as polluted from the color of its turbidity, the community can take action to reduce the level of water turbidity by filtering or by making repairs if the pipe leaks.

2 Related Research

In research [9] regarding object sorting robots based on the TCS3200 color sensor, there is the system's main program, namely the recognition of object colors and placing objects in a predetermined place. In this study, color testing was first carried out on the color sensor calibration process used on all color objects to be stored in the microcontroller EEPROM database as a reference for RGB color data objects. Calibration is done by placing a white object under the DT-SENSE color sensor lens called white balance and a black object called black balance.

A similar study [10] used the TCS3200 sensor regarding color detection in beverage cans. In this study, the test materials were in the form of three beverage cans with different brands, including a red Fanta drink, a green milo drink, and a blue polari sweat drink. Testing the tool with each drink can is done by placing the drink can at the sensor position, and then the RGB data value of the serial monitor will be read with a certain intensity value.

Research [11] using a color sensor has also been carried out using the MQTT protocol to monitor rice's age. The tests carried out in this study were three times. First the test for the sensor color experiment.

In the study [12], the TCS3200 color sensor was used to identify fresh meat. In this study, the tool works by measuring the RGB color components of the identified meat and comparing it with the color composition of the fresh reference meat. This study does not use data communications such as HTTP or MQTT because the research results are displayed only through an LCD screen.

A similar study [13] has also been carried out using the TCS3200 color sensor to create a classification system for pure white and white tofu containing formalin. In this study, testing was carried out using the K-Nearest Neighbor (K-NN) method, which aims to determine and see the classification level of the test object from the method.

This related research used it as a reference for designing a water turbidity classification system in households using the TCS3200 color sensor with Message Queuing Telemetry Transport (MQTT) data communication. The classification results will be displayed through a website page with the microcontroller used, namely the Wemos D1 Mini which has a 32-bit 80 MHz processor. So, in research conducted by researchers, researchers used the TCS3200 color sensor with a different object from related research, namely by using cloudy water in households that were polluted due to mud, moss, soil, and lime content. This research is expected to help the community find out whether the water used for household needs is polluted or not so that it can minimize side effects that are not good if used for daily needs.

3 Review of the Presented System

3.1 System Requirements

In the system requirements analysis stage, the system will analyze the development requirements. The analysis to be carried out includes an analysis of the needs for tools and materials, including hardware and software, as follows:



Fig. 1. General View of The System

- The laptop will be used as a medium to build the system and display the website during system testing.
- The operating system used is Windows 11.
- 1 Wemos D1 Mini is used as a microcontroller.
- 1 TCS3200 color sensor is used to detect the color of water turbidity in the household.

It supports applications in making the system, namely a text editor as an application to build a website using HTML, CSS (Bootstrap), and JQuery. XAMPP is also an application intended as a website server using the Apache HTTP Server and database processing using a MySQL database with the output displayed on the website page as shown by Fig. 1.

3.2 System Architecture Design

The following is an explanation of each process and the relationship between processes contained in Fig. 2:

1. The color sensor TCS3200 (A) is used to measure the RGB (Red, Green, Blue) color of cloudy water in the household.
2. The Wemos D1 Mini (B) microcontroller retrieves data from RGB value output on the TCS3200 color sensor. The ESP8266Wifi library connects to the internet and the PubSubClient library, which connects with the broker server as a client.
3. Broker server (C), which the client will address in the delivery of data using the MQTT communication protocol installed on the laptop.
4. Laptop (D) is an electronic device used to classify the results of turbidity detection in watercolour. The result of the classification will be displayed on a website page to see if the cloudy water is caused by mud, moss, soil, or lime content.

At the stage of testing and evaluating the system, testing the system that has been built will be carried out. In this study, the testing technique used is the black box method for testing the water turbidity classification system in households because this black box testing method serves to determine the performance of the system that has been built. The testing stages are as follows:

1. System testing using black box testing is carried out on the water turbidity classification system. Tests are carried out to observe and analyse the functionality of the features in the water turbidity classification system to ensure whether the system performance has been running as desired and has been able to perform the classification according to the actual results.

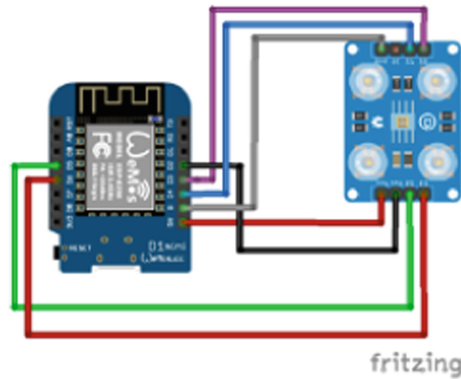


Fig. 2. Circuit of The System

Table 1. Average RGB Between Labels

Label	R	G	B
Clear	165	149	172
Moss	56	76	68
Mud	40	38	49
Lime	203	212	195
Mud	67	76	65

2. Testing the feasibility of the system’s function that has been made, namely by calculating the results obtained from the RGB output of the water data sampled with the water data output that will be tested to get the results of the classification of the causes of turbidity.

Table 1 is an example of the average RGB value output for each sample obtained from calculations on the microcontroller. Mud water has an RGB value: 67 67 65. The water to be tested has an RGB value: 80 74 83. After subtraction, the RGB value of 13 7 18 with a total of 38 divided by three, resulting in a value of 12.67.

The difference in the value of the mud water and the tested water. Then the same calculation is carried out on other water data (moss water, groundwater, lime water, and clear water) with the tested water. The resulting value after deducting is the absolute value that will be the benchmark for identifying the classification results. The result of the calculation that has a minor difference will be the final identification of whether it is included in clear water/mud water/moss water/groundwater [9].

S = value, M = average, SD = standard deviation. The calculation scenario is that each sample variable (R, G, B) is calculated to get the average and then looks for the standard deviation value. After getting the standard deviation value of each variable from

Skor	Kategori
$s \geq (M + 1 \text{ SD})$	High (tinggi)
$(M - 1 \text{ SD}) < s < (M + 1 \text{ SD})$	Moderate (sedang)
$s \leq (M - 1 \text{ SD})$	Low (rendah)

Fig. 3. The Category and Score

each sample, these values are added up and divided by 3 (because the variables are R, G, and B).

The average calculation of the standard deviation results will be used as a benchmark according to the guidelines in Fig. 3. Then to find the M value (average) by calculating the average of each variable (R, G, B) for each sample then, the results are added up and divided by 3 (because the variables are R, G, B).

Then to find the value of s, namely the test data that was tested 30 times, the average of each variable (R, G, B) will be calculated, then the average of each variable is added up and divided by 3 (R, G, B). When all the values in the guidelines are known, the result will be the turbidity level, whether in the high, medium, or low category.

4 Detail of the Presented System

4.1 Hardware Realization

The realization of the hardware arrangement of the Water Turbidity Classification System in Households Based on the IoT Color Sensor TCS3200 refers to the hardware design made in the previous chapter.

In Fig. 4, two kinds of hardware are assembled into a tool or system to detect objects in the form of cloudy water. The system consists of the Wemos D1 Mini and the TCS3200 Color Sensor. The functions of each of these tools are as follows:

1. Wemos D1 Mini is used as a microcontroller that functions to capture RGB values on detected objects and then sends data to the broker using the MQTT data communication protocol based on specific topics.
2. Color Sensor TCS3200 is used to read the RGB value of the detected object.

4.2 Software Realization

The web of water turbidity classification system in households was developed using the PHP programming language. In the discussion of the previous chapter, it has been explained in the use case diagram in Fig. 5 that one actor or user runs the system.

Figure 5 is the realization of the interface on the dashboard page. The dashboard page displays the number of conditions of water turbidity that have been detected, namely, water contaminated with soil has been detected five times, water contaminated with moss has been detected ten times, water contaminated with lime has been detected eight times, and water contaminated with mud has been detected nine times.

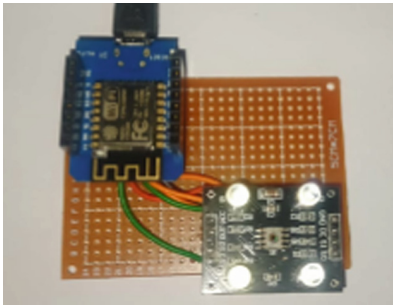


Fig. 4. Realization on PCB

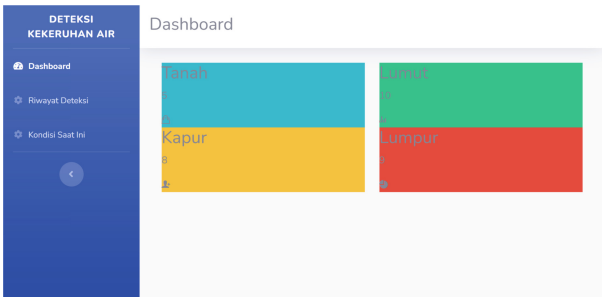


Fig. 5. Dashboard

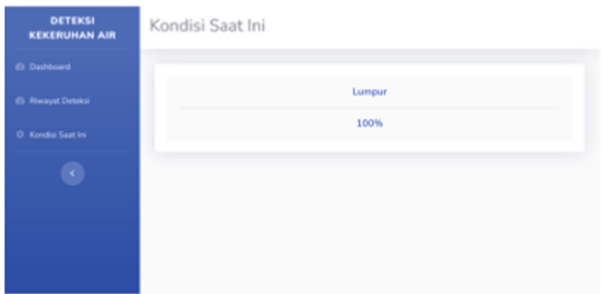
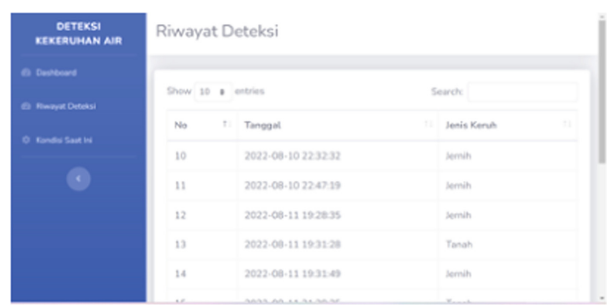


Fig. 6. Detection Result

Figure 6 shows the realization of the interface on the page in its current state. This page displays information on the cause of the currently detected water turbidity, and the turbidity level is 100%.

Figure 7 is a realization of the interface on the detection history page. This page contains information in the form of a table related to the history of water turbidity detection results that have been detected previously by displaying the date column and the time and type of cloudiness.



The screenshot shows a web application interface. On the left is a blue sidebar with the title 'DETEKSI Kekeruhan Air' and menu items: 'Dashboard', 'Riwayat Deteksi', and 'Kontrol Suhu Air'. The main content area is titled 'Riwayat Deteksi' and contains a table with 5 columns: 'No', 'Tanggal', 'Jenis Keruh', and two unlabeled columns. The table lists 5 entries with dates from 2022-08-10 to 2022-08-11 and turbidity types like 'Jernih' and 'Tanah'.

No	Tanggal	Jenis Keruh		
10	2022-08-10 22:32:32	Jernih		
11	2022-08-10 22:47:19	Jernih		
12	2022-08-11 19:28:35	Jernih		
13	2022-08-11 19:31:28	Tanah		
14	2022-08-11 19:31:49	Jernih		

Fig. 7. Detection History

5 Result and Evaluation

5.1 Black Box Testing

Black box testing is carried out to observe and analyze the functionality of the features in the water turbidity classification system to ensure whether the system performance has been running as desired or not and has been able to perform the classification according to the actual results. The results of the black box testing can be seen in Table 2.

5.2 Overall System Test Results

The overall system function test was carried out on August 14, 2022, using 5 types of water, namely clear water, water mixed with soil, water mixed with lime, water mixed with moss, and water mixed with mud as shown on Table 3.

Table 2. Black Box Testing

No	Features	Expected results
1	Wemos D1 mini can read sensor	Read
2	Wemos D1 mini can connect to MQTT Broker on laptop	Connect
3	Wemos D1 mini can send data to laptop	Sent
4	Laptops can store data in the MySQL database	Stored in the Database
5	Websites can display data from MySQL	Displayed
6	Websites can display different data for the type of turbidity	Displayed

Table 3. Statistics Summaries Of Whole Data

	R	G	B
count	1000	1000	1000
mean	292.898	347.063	294.716
std	72.381646	89.051902	67.080706
min	177	210	188
25%	220	254	225
50%	341	411	340
75%	353	421	350
max	367	433	366



Fig. 8. Experiment condition

Figure 8 is a tin container with a silver base colour used for testing. In the lid of the container, a hole is made the size of the colour sensor. The purpose of making the hole is so that the container can be closed properly to minimize the intensity of light from around and so that the sensor can stay in its position.

Figure 9 is the result of the currently detected water turbidity. This page displays the type of water turbidity, namely lime, with a turbidity level of 97%. The correlation matrix between all variables in the research is shown in Table 4. The table shows that whole R, G and B have a high positive correlation.

Figure 10 is a graph comparing R and G values in the collected water sample data. It can be seen in the graph related to the comparison of each sample data that lime and clear samples have significant differences from other samples, while mud, mud and soil samples have similar values and soil samples with mud are even almost similar, so that it can be seen in Fig. The sample graphs overlap each other.

Figure 11 is a graph of the comparison of the R and B values in the water sample data that has been collected. It can be seen in the graph related to the comparison of each sample data that lime and clear samples have significant differences from other samples,

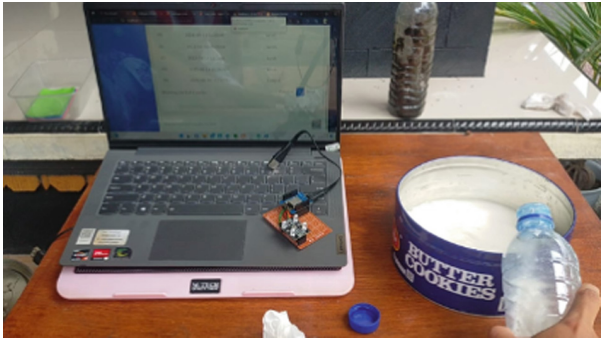


Fig. 9. Example of Experiment

Table 4. Correlation Matrix

	R	G	B
R	1	0.992878	0.991504
G	0.992878	1	0.99342
B	0.991504	0.99342	1

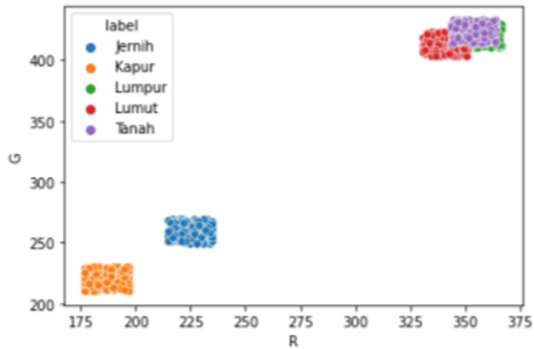


Fig. 10. Scatter Plot between R and G

while mud, mud and soil samples have similar values, but in this graph, the soil and mud samples have different values. Almost similar so that it can look like the sample graph.

Figure 12 is a graph of the comparison of the values of G and B in the water sample data that has been collected. It can be seen in the graph related to the comparison of each sample data that lime and clear samples have significant differences from other samples, while mud, mud and soil samples have similar values and soil samples with mud are even almost similar, so that it can be seen in Fig. The sample graphs overlap each other.

Table 5 shows the data summary of the water mixed with soil, Table 6 for the moss and Table 7 for the mud. Each data has a similar value from mean, standard deviation,

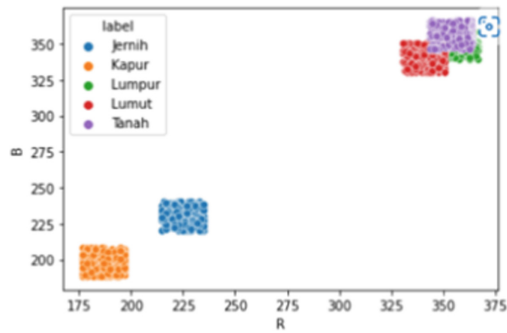


Fig. 11. Scatter Plot between R and B

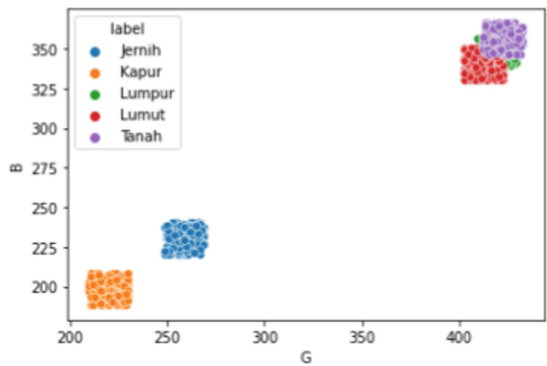


Fig. 12. Scatter Plot between G and B

Table 5. Statistic Summary of Soil

	R	G	B
Count	200	200	200
Mean	354.18	423.89	355.46
Std	6.117	5.896	5.838
Min	344	413	346
25%	349	419	351
50%	354	424.5	355
75%	360	429	360
Max	364	433	366

minimum, low sub median (25%), Midian (50%), high sub median (75%) and maximum value.

Table 8 shows the data summary of the clear water, and Table 9 for the water mixed with lime. Each data has a comparable value from mean, standard deviation, minimum,

Table 6. Statistic Summary of Moss

	R	G	B
Count	200	200	200
Mean	340.725	412.78	340.585
Std	6.226	6.148	6.027
Min	331	403	330
25 %	335.75	407.75	336
50 %	341	412.5	340
75 %	346	418	346
Max	351	423	350

Table 7. Statistic Summary of Mud

	R	G	B
count	200	200	200
mean	357.375	419.815	349.365
std	6.042	5.968	5.897
min	347	410	339
25 %	352	415	345
50 %	357	420	349
75 %	363	425	355
max	367	430	359

Table 8. Statistic Summary of Clear

	R	G	B
count	200	200	200
mean	225.05	258.685	230.185
std	6.271	5.751	5.996
min	215	249	220
25 %	220	254	225
50 %	225	258	231
75 %	230	264	235.25
max	235	269	240

Table 9. Statistic Summary of Lime

	R	G	B
count	200	200	200
mean	187.16	220.145	197.985
Std	5.842	6.194	5.905
Min	177	210	188
25%	182	215	193
50%	188	220	197.5
75%	192	225	204
max	197	230	208

low sub median (25%), Midian (50%), high sub median (75%) and maximum value but still can be comparable and have an exact distance.

6 Conclusion

Based on the research and testing that has been carried out, the following conclusions can be drawn:

1. The classification system website page can display data from current water conditions and detection history obtained using the MQTT protocol.
2. Based on black box testing, it can be concluded that all functions have been running properly, and the system can perform classification well.
3. Experiments using different containers show that the system can perform the classification as expected if it is calibrated first on each container.
4. Based on the graph of RGB values, mud, moss, and soil have relative RGB values.

Tests carried out with closed containers can produce a better classification than containers with open conditions because light intensity influences the surroundings.

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