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Article

Detecting Dehydration Based on Urine Color Using Fuzzy Logic Image Processing and Regulating Water Intake with an Automatic Water Pump According to Dehydration Level Using an IoT-Based

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Abstract: Dehydration is a condition where the body lacks the fluids it needs to carry out its functions optimally. Dehydration can cause various health problems, including decreased mental and physical performance, and can even cause death if not treated immediately. Therefore, it is important to be able to detect and treat dehydration early. One way to detect dehydration is through urine color analysis. Urine that is darker than normal can be a sign of dehydration. The classification of dehydration level according to urine color is as follows: 1-2: Hydrated, 3-4: Mildly dehydrated, 5-6: Dehydrated, 7-8: Very dehydrated. This research aims to develop an IoT-based dehydration detection system that can detect the level of dehydration in a person based on urine color and regulate water intake automatically using a water pump. The novelty of this research is the method of integrating drinking water intake with dehydration detection based on real-time urine color based on IoT using the Fuzzy Logic method. The results of this research are used by the Jember State Polytechnic TeFa Nutrition Care Center (NCC) in serving patients. The methodology used in this research is Fuzzy Logic image processing to process urine color data and determine a person's level of dehydration. After carrying out this research, the following conclusions were obtained: Based on the literature study in this research, 8 levels of hydration status according to NSW Health were obtained, then from this literature a method was obtained to measure a person's hydration based on urine color using image processing using the Fuzzy Logic method.

Keywords: dehydration; IoT system; image processing,

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1. Introduction

Dehydration is a serious medical condition and can affect an individual's health and well-being. However, many people are unaware or do not fully understand the importance of adequate hydration and a lack of it can affect their health. [1] One way to detect dehydration is through urine color analysis. Urine that is darker than normal can be a sign of dehydration. [2]

Therefore, this research was conducted to develop technology that can help individuals monitor dehydration levels and regulate water intake more effectively and efficiently, as well as increase individual awareness of the importance of hydration in maintaining health.

This research uses the method of image processing to classify the degree of dehydration based on urine color, as well as the fuzzy Inference System to determine drinking water needs according to the level of dehydration. This method was developed with the aim of developing technology that can help individuals monitor their health independently and increase awareness of the importance of hydration in maintaining health and well-being. In this research, IoT (Internet of Things) will be used as a means to automatically control the water pump according to the individual's level of dehydration. Data collected from the urine color sensor will be sent via an internet connection to the Fuzzy Inference System, and the results will be used to regulate the water pump via IoT. By using IoT technology, individuals can regulate water intake automatically and accurately, without the need to make manual settings. This can make it easier for individuals to control their water intake and help maintain their health and well-being more effectively. By combining the technology of image processing, Fuzzy Inference System, and IoT, this research is expected to provide more accurate and effective results in detecting dehydration levels and determining appropriate drinking water needs.

Dehydration is a condition in which the body loses more fluid than is necessary to maintain fluid balance in the body. This condition can be caused by various factors such as not drinking enough water, heavy physical activity, diarrhea, vomiting, and fever. One indicator commonly used to determine the level of dehydration is the color of urine. [3] Hyperosmolarity is frequently linked to dehydration. But as was previously said, depending on the degree of related salt loss, dehydration can result in a variety of osmolar states. [11] The other research Dehydration also ever to chronic kidney disease (CKDu) in Sri Lanka [3]

A darker urine color can be an early indicator of dehydration. Darker urine color and higher urine viscosity are associated with decreased plasma volume and increased serum osmolality. [4]–[6] Urine color can be used as an indicator to determine body fluid needs. Darker urine color may indicate a higher water need. Habitually consuming less water was linked to higher body fluid contents [24] . People who consume sufficient amounts of water tend to have lighter urine color and lower urine viscosity [7], [8].

A study used computer vision technology for real-time [9] to estimate the level of dehydration based on the color of urine in mice. The research used a camera to take images of mouse urine and processed them with computer vision technology. Image processing is carried out by converting the image into HSV mode (hue, saturation, value) color space denotes the intensity or lightness or brightness of the color[10]. and using a clustering algorithm to classify urine color into three categories: normal urine, urine with a mild level of dehydration, and urine with a severe level of dehydration. [4]–[6]

Several studies have also been carried out to determine the appropriate drinking water needs according to the level of dehydration [11]. In the current era, water is a significant resource for socio-economic growth and the protection of healthy environments [12] . Dehydration of as much as 2% of body weight can cause a decrease in plasma volume and an increase in serum osmolality. Serum osmolality is the sum of the osmolalities of every single dissolved particle in the blood such as sodium and associated anions, potassium, glucose, and urea [13]. However, increasing water intake can improve the condition. So that adequate water intake can minimize the risk of dehydration during intense physical activity, especially in running athletes. Additionally, special attention needs to be paid to the dangers of dehydration and its serious repercussions [14].

Based on data released by the Ministry of Health, it shows that adults need at least 2.5 to 3.5 liters of water per day, depending on activity level and environmental temperature. However, individual water needs may vary based on factors such as age, gender, and health status. [15]

[8] Several recent studies have succeeded in developing machine learning models that are capable of classifying the level of dehydration based on urine color with high accuracy. For example, studies using techniques of image processing and deep learning

to classify urine color based on the degree of dehydration. The results show that the model developed can classify the level of dehydration with an accuracy of 97.3% [16]. Sometimes the FIS with neural network learning systems to improve the approximation ability [17].

In addition, several studies have succeeded in integrating IoT technology with a Fuzzy Inference system to determine drinking water needs based on an individual's level of dehydration. For example, a study by Aditya et al used an IoT system to monitor dehydration levels in patients with chronic liver disease and provide appropriate water intake recommendations.[18]

The novelty of this research is the method of integrating drinking water intake with dehydration detection based on real-time urine color based on IoT using the Fuzzy Logic method.

2. Materials and Methods

Materials

1. ESP8266 IoT kit
2. TCS 3200 RGB Sensor
3. Breadboard
4. IoT Server
5. Web Server Apache
6. MySQL Database Server
7. PHPMyAdmin
8. Jumper cable
9. Test tube bottle

Methods

In general, this research was carried out according to the block diagram as seen in Figure 1 below.

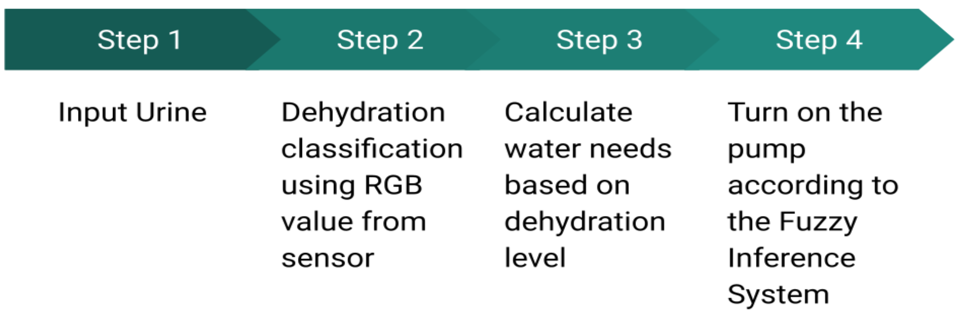


Fig. 1. Research Flow Block Diagram

2.1. Input Urin

Based on the urine fluid sample, color detection is carried out directly using the TCS3200 sensor to obtain the R(R) G(Green) B(Blue) value. [1]

2.2. Determining classification using RGB values from sensors

Determination of Hydration levels based on urine color are carried out using value readings from the TCS3200 sensor with a few steps:

1. The urine sample is placed in a glass/test tube

2. The liquid in the test tube is detected using the TCS3200 sensor module

3. The RGB value data obtained from the TCS3200 readings is compared with a database containing hydration data based on references taken from NSW Health [19]. As explained in table 1 below.

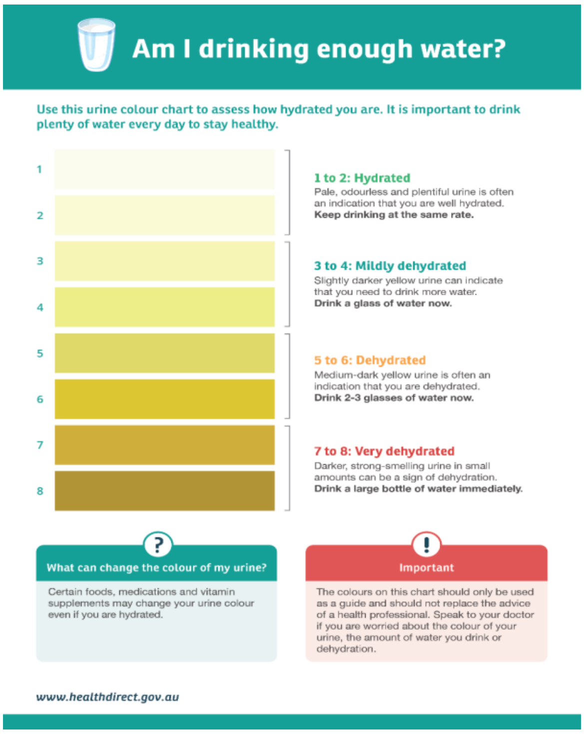


Fig. 2. Urine Color Chart [19]

According to NSW Health in the image above, to determine a person's hydration status, can be obtained from the urine color extracted from the image into an RGB value using the Matlab application app2.mlap in Figure 3 Image Preprocessing.

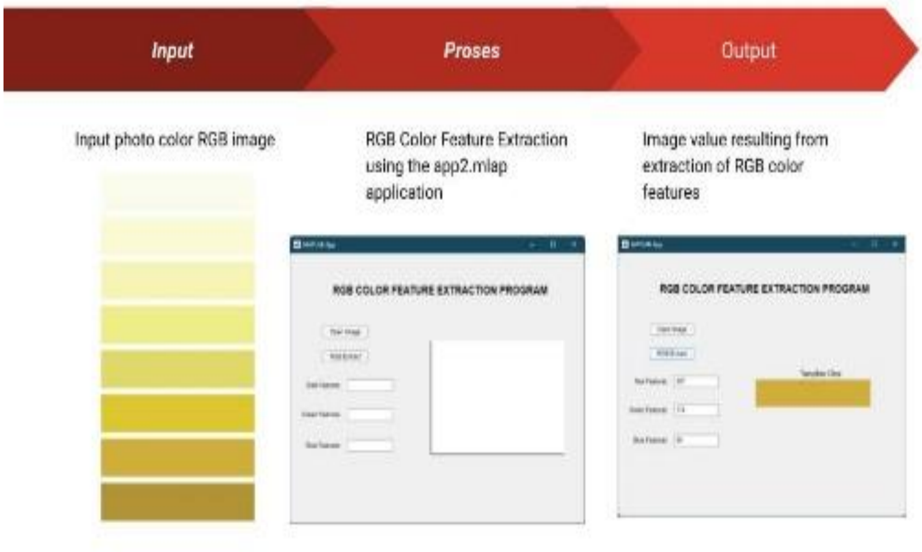


Fig. 3. Prepocessing Image

Based on the preprocessing carried out, the table obtained in Table 1 is as follows:

Table 1. Hydration Based on Urine Color

No	Mark			Hydration Status
	Red	Green	Blue	
1	251	252	238	Hydrated
2	250	250	213	Hydrated
3	246	245	181	Mildly Dehydrated
4	237	238	136	Mildly Dehydrated
5	237	217	105	Dehydrated
6	220	199	51	Dehydrated
7	207	174	59	Very Dehydrated
8	176	148	53	Very Dehydrated

Based on Table 1 above, hydration status is determined as follows: 1-2: Hydrated, 3-4: Mildly dehydrated, 5-6: Dehydrated, 7-8: Very dehydrated. [19]

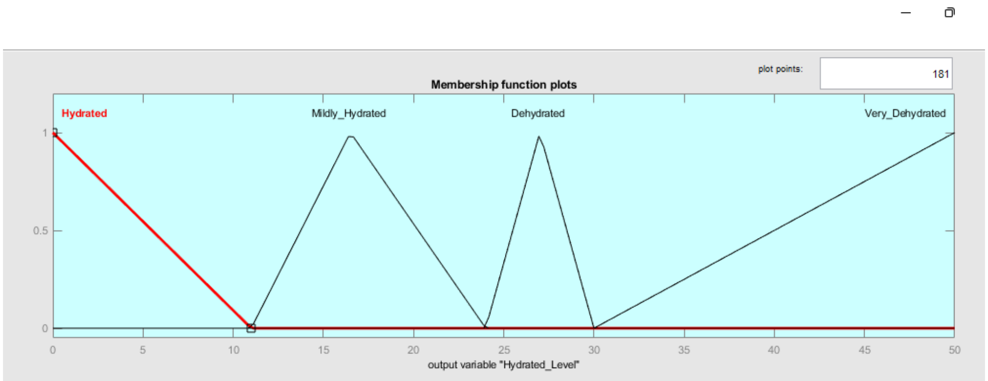


Figure 3. Membership function of Output Variabel Hydrated Level

Figure 3 shows the membership function on the hydration level output variable [19]

2.3. Calculating Water Needs Based on Dehydration Level

The following are the steps for calculating water needs using FIS based on urine color:

1. Determine variable input What will be used is the level of urine viscosity , which can be measured based on the color of the urine. [20]
2. Define the output variables that will be used to determine the state hydration as a determinant of drinking water needs.
3. Determine fuzzy rules that can be made based on expert knowledge obtained from journals.
4. Fuzzy rule evaluation: Evaluate fuzzy rules to determine membership values for each output variable.
5. Calculate weights: Calculate the weights for each output variable. The weight shows the contribution of each output variable in determining the value of water requirements.

6. Calculate defuzzyfication value: Compute the defuzzyfication value for the output variable. The defuzzification value is a value that describes the appropriate water requirements based on the measured urine viscosity level

2.4. Turning on the Pump Based on the Fuzzy Interference System

After obtaining the hydration level, the next step is to determine whether the water pump will turn on until the required water is met using IoT-based equipment which will be published later

3. Results and Discussion

This research aims to develop an innovative system for monitoring individual hydration levels based on urine color analysis. The design of this system begins with taking a urine sample, which will then be analyzed for color using the TCS3200 color sensor. The RGB values resulting from urine color analysis will be sent to the IoT web server via the ESP8266 module, and then processed to determine a person's hydration level. After the hydration level can be determined, the second ESP8266 module will be given a command to activate the 1 channel 5v relay which controls the water pump so that water can be released into the bottle. When the bottle is completely filled, the ultrasonic sensor will signal the ESP8266 to deactivate the relay and stop the water pump, thus ensuring optimal filling of the bottle with water according to the individual's measured hydration level. Thus, this system provides an effective solution for monitoring and automatically meeting individual hydration needs. The technical explanation of this IoT tool will be explained in more detail in the next journal publication.

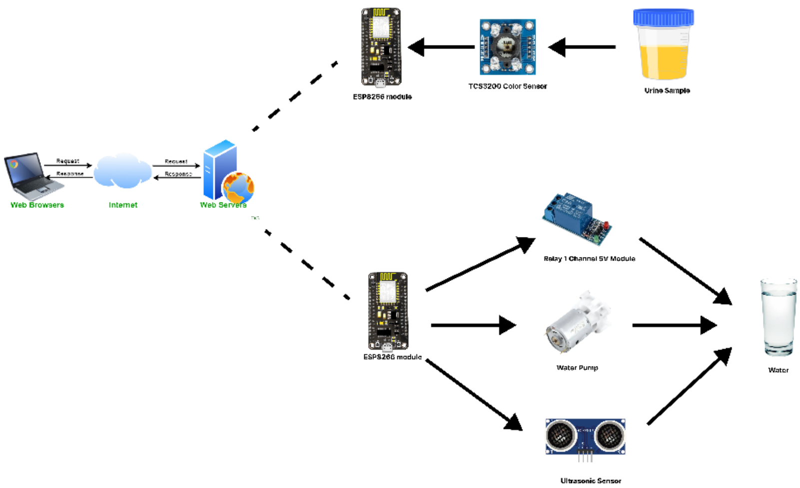


Figure. 4. System Concept Diagram

The process on this device involves several steps that must be gone through before finally being able to calculate the amount of water needed by the user.

1. Urine Image Capture

In this device, the sensor used is the TCS3200 sensor to obtain urine values. The values obtained from this sensor are Red (R), Green (G), and Blue (B). Then the value generated from the sensor is used as material to classify a person's level of dehydration. In this system, the method used to classify is Fuzzy[21].

2. Classification of dehydration levels based on urine color

In this system to classify the level of dehydration using the Fuzzy method. In system design, fuzzy variables will be created where fuzzy can help in decision-making. This fuzzy method of control has 3 inputs, namely Red, Green, and Blue, and produces 3 outputs, namely normal, dehydration, and severe dehydration. [22] The membership function of each input variable can be seen in the picture

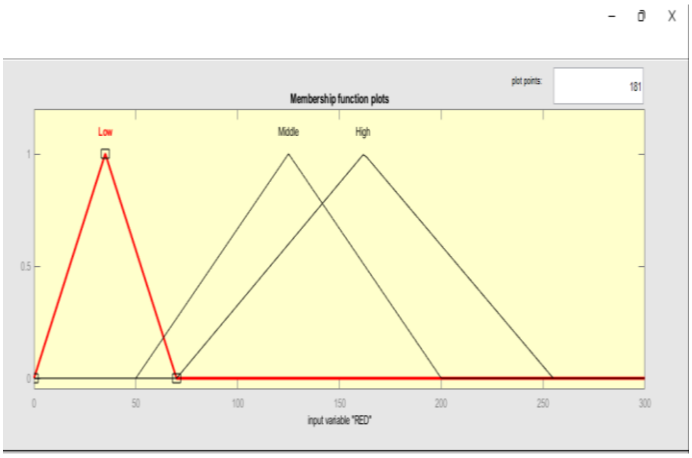


Figure 5. Membership Function of RED

In the picture above, the membership function for the RED input variable with the following universe is explained:

Table 2. Input Variable of RED

Input Function	Variable	Universe of Conversations
Red	Low	0-70
	Currently	50-200
	Height	70-255
Green	Low	0-70
	Currently	50-200
	Height	70-255
Blue	Low	0-70
	Currently	50-200
	Height	70-255

In the table 2 above, explains the membership function for Red

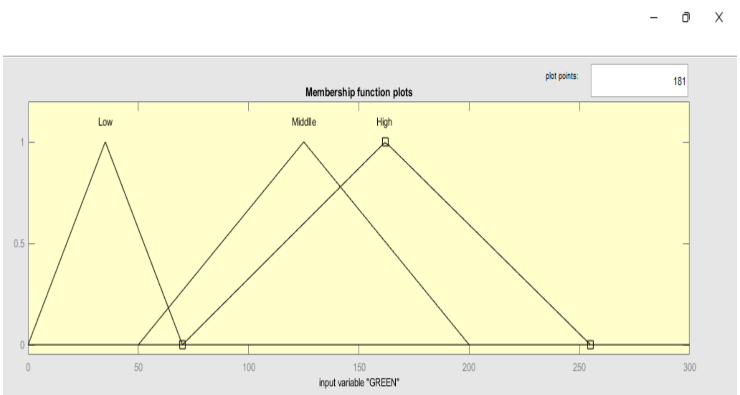


Figure 6. Membership Function of GREEN

In the picture above, the membership function for the GREEN input variable with the universe is explained as follows:

Table 3. Input Variable GREEN

Input Function	Variable	Universe of Conversations
Red	Low	0-70
	Currently	50-200
	Height	70-255
Green	Low	0-70
	Currently	50-200
	Height	70-255
Blue	Low	0-70
	Currently	50-200
	Height	70-255

In the table 2 above, explains the membership function for GREEN

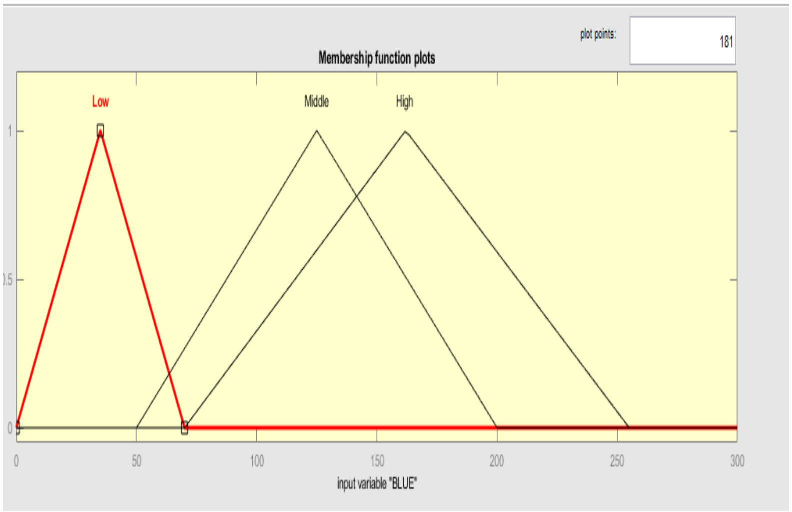


Figure. 7. Membership Function BLUE

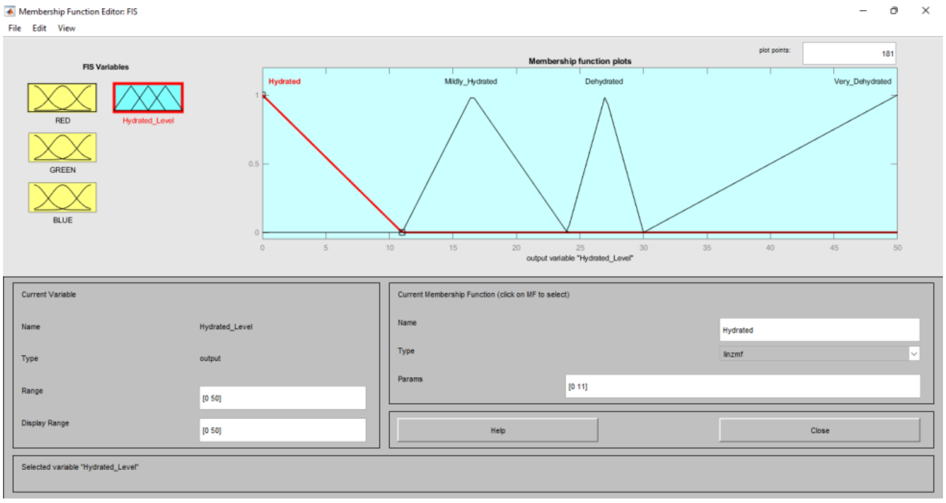
In the picture above, the membership function for the input variable BLUE with the universe is explained as follows:

Table 4. Input Variable BLUE

Input Function	Variable	Universe of Conversations
Red	Low	0-70
	Currently	50-200

	Height	70-255
Green	Low	0-70
	Currently	50-200
	Height	70-255
Blue	Low	0-70
	Currently	50-200
	Height	70-255

In the table 2 above, explains the membership function for BLUE



After determining the membership function for each input variable [12] and output variabel, the next step is to create a rule. At this stage, each output from the fuzzification stage in the form of membership degrees and linguistic variables will be combined using an evaluation rule [23]. In rule evaluation, there are linguistic rules to determine the control action on the input value from defuzzification. In this step, use the rule (IF…AND…THEN). The rules created in Table 5 are as follows:

Table 5. Rules of Fuzzy Inference System Hydration System Using RGB Image Processing

No	Rules	Result
1	If RED is High and GREEN is High and BLUE is High	Hydrated
2	If RED is Low and GREEN is Low and BLUE is Low	Dehydrated
3	If RED is Low and GREEN is Low and BLUE is Middle	Very Dehydrated
4	If RED is High and GREEN is Middle and BLUE is Low	Mildly Hydrated
5	If RED is High and GREEN is Middle and BLUE is Low	Mildly Hydrated
6	If RED is Middle and GREEN is Middle and BLUE is Low	Mildly Hydrated
7	If RED is Low and GREEN is Low and BLUE is Low	Mildly Hydrated
8	If RED is Low and GREEN is Low and BLUE is Low	Mildly Hydrated
9	If RED is Low and GREEN is Middle and BLUE is Low	Mildly Hydrated
10	If RED is High and GREEN is Low and BLUE is Low	Mildly Hydrated

No	Rules	Result
11	If RED is Middle and GREEN is Low and BLUE is Low	Mildly Hydrated
12	If RED is Middle and GREEN is Low and BLUE is Low	Mildly Hydrated
13	If RED is Middle and GREEN is Middle and BLUE is Middle	Dehydrated
14	If RED is Middle and GREEN is Middle and BLUE is Middle	Dehydrated
15	If RED is Middle and GREEN is Middle and BLUE is Middle	Dehydrated
16	If RED is High and GREEN is High and BLUE is Middle	Very Dehydrated
17	If RED is Low and GREEN is Middle and BLUE is Low	Mildly Hydrated
18	If RED is Low and GREEN is High and BLUE is High	Mildly Hydrated
19	If RED is Low and GREEN is High and BLUE is High	Mildly Hydrated
20	If RED is High and GREEN is Middle and BLUE is Low	Mildly Hydrated
21	If RED is High and GREEN is Middle and BLUE is Low	Mildly Hydrated
22	If RED is Middle and GREEN is High and BLUE is High	Mildly Hydrated
23	If RED is Low and GREEN is Low and BLUE is Low	Dehydrated
24	If RED is Middle and GREEN is Middle and BLUE is Middle	Dehydrated
25	If RED is High and GREEN is Low and BLUE is Low	Dehydrated
26	If RED is Middle and GREEN is Middle and BLUE is Middle	Dehydrated
27	If RED is High and GREEN is Middle and BLUE is Middle	Dehydrated

In Table 5 above, the FIS Hydration System Rules are explained in accordance with literature obtained from NSW Health [19].

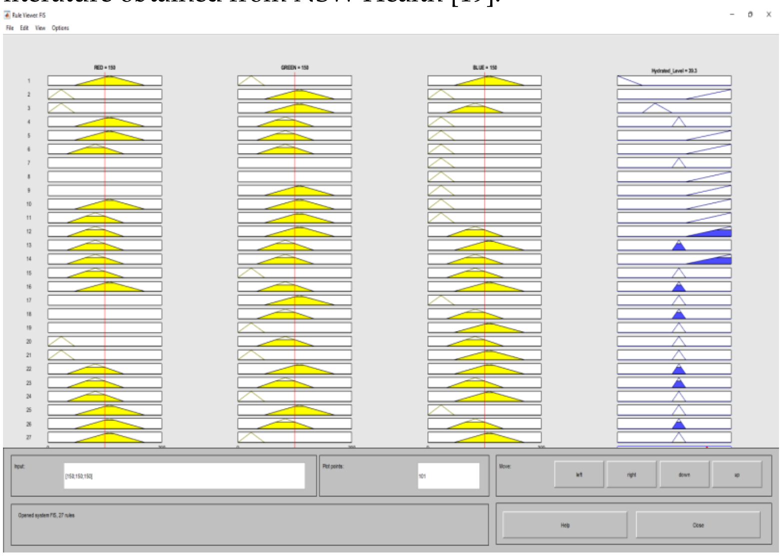


Figure 8. Rule Viewer

Figure 8 explains the Rule Viewer dehydration system.

3. Calculate the length of time the water pump is on

The length of time the water pump is on is determined using an Ultrasonic (Distance) sensor by measuring the distance between the sensor and the water level.

Figure 9. Web Application of Dehydration Detection

Figure 10. Databse of Application

In the picture above, the physical database diagram of the dehydration system web application is explained, which consists of 5 main tables in the database

4. Conclusions

After carrying out this research, the following conclusions were obtained: Based on the literature study in this research, 8 levels of hydration status according to NSW Health were obtained, then from this literature a method was obtained to measure a person's hydration based on urine color using image processing using the Fuzzy Logic method.

Author Contributions: Denny Trias Utomo and Adi Heru Utomo Conceptualization, Methods Coding and Web Developing application; validation, investigation, resources, formal analysis, data curation Zora Olivia and Nita Maria., Nilla Putri Rosidania.; writing—original draft preparation, writing—review and editing,

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