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IoT Flood Monitoring System

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Abstract: Floods have occurred badly lately in some areas around Malaysia. It happens suddenly and affects a wide variety of people and buildings. Most people lack access to reliable knowledge about weather patterns and hence are unable to predict when the next flood will come. The main objective of this project is to develop and design an Internet of Things (IoT) flood monitoring system that is able to detect potential flooding conditions. This project consists of an ultrasonic sensor (HC-SR04) used to detect the height of the flood water in a laboratory-scale terrain modal for flood submergence simulation. A Durian UNO acts as a microcontroller in this system while the WIFI module (ESP-01S) is to send data from the microcontroller to the Blynk application. This system is also equipped with a buzzer, which would be activated once the flood water level passes a certain threshold value which is 5 cm and it would display on the "Liquid Crystal Display" (LCD) "HIGH" or "LOW". Once exceeded the value, the system would then send an alert notification through the Blynk application and also display a real-time image of the flood on the user's smartphone. This IoT flood monitoring system would help to alert its users about the presence of flood, thus saving human lives and properties in flood-prone locations.

Keywords: Flood, Internet of Things (IoT), Ultrasonic sensor

1. Introduction

Malaysia, like any other country, is vulnerable to floods because of the occurrence of this natural hazard. High water flows that exceed the capacity of man-made or natural barriers are considered floods and can occur anywhere along the river system. As a result, when a riverbank is overtopped, water spills over the flood plain, posing a hazard to civilization that can cause significant loss of life, disease transmission, property damage, and economic loss. The Malaysian Drainage and Irrigation Department classifies floods in Malaysia as flash floods, tidal floods, and monsoon floods [1].

Climate change in Malaysia is very unpredictable as it can be sunny now and start raining continuously at the next moment, making it hard for scientists to understand where and when flood calamity would occur. Due to this, predictions cannot be made to warn the people. On the 16th of December 2021, eight states in the peninsula were flooded as a result of three days of severe rain. In

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addition, the flood claimed the lives of 54 people and left two persons missing, affecting over 125,000 people in total [2][3].

Several works have been carried out to address the problem. [4] used SMS to receive text messages with updates on the current water level. When the water level drops below a certain threshold, a text message is sent to the user's phone through the Global System for Mobile Communications (GSM) module, while the Arduino Uno's central processing unit (CPU) analyses the input from the pressure sensor and determines the water level. The disadvantage of this system is that it uses a pressure sensor which has a complex formulation and also the SMS which adds financial problems to the user once the message is received.

The work in [5] describes flood alert, an intelligent system that detects the amount of water in specific areas so that homeowners may prepare for floods and reduce the damage they cause. Using IoT sensor technology, the system determines the water level and rate of water flow. In the event of a flood in a subscribing user's location, an alarm would be activated. Some of the disadvantages of this system are that the Raspberry Pi board is too expensive and the water level sensor might rust, foul, and deteriorate over long-term use. When compared to these projects, the system employed in this study has the benefit of being able to provide messages to users promptly, directly, and quickly, in fact, the fastest. This notification can be accessed through the Blynk, which is loaded on each user's smartphone. This system uses the most up-to-date technology, known as the Internet of Things (IoT), which has the incredible ability to transfer any information wirelessly.

2. Methodology

2.1 Block diagram

Figure 1 shows the schematic block diagram of the system operation. This operation started with the ultrasonic sensor which is the main component in this system in detecting the height of the water level. Then it moves to the Durian UNO which is the microcontroller in this system. When the water level is detected to be low, the LCD displays a low on it whereas when the water level is high, it displays a high, and the buzzer triggers. When the buzzer is still triggering, it also sends a notification on the Blynk application which alerts the user to see their camera application to view the real-time image of the water.

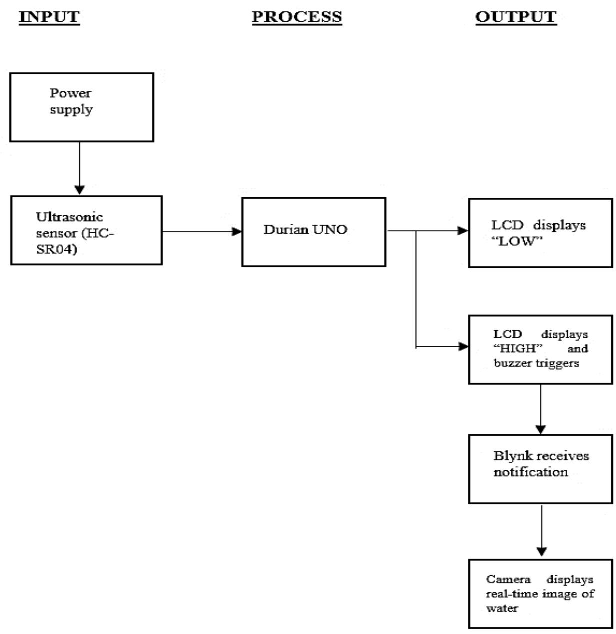

Figure 1: System block diagram

2.2 Flow chart

Figure 2 shows the overall flowchart of the developed water level monitoring system integrated with an ultrasonic sensor. This simple circuit is connected to a Durian UNO microcontroller and it starts by initializing the port which is declared beforehand. Then, an ultrasonic sensor is placed at a certain height within the miniature "flooding model". The function of the ultrasonic sensor is to measure the height of the water. When the water level rises from the ground level, the Liquid Crystal Display (LCD) would display if the water level is high or low. If the water level passes over the threshold value of 5 cm, the buzzer would trigger, which serves as an alarm warning. Moreover, the camera would show a real-time image of that scenario. The server would then get all the data regarding the flood water in Blynk.

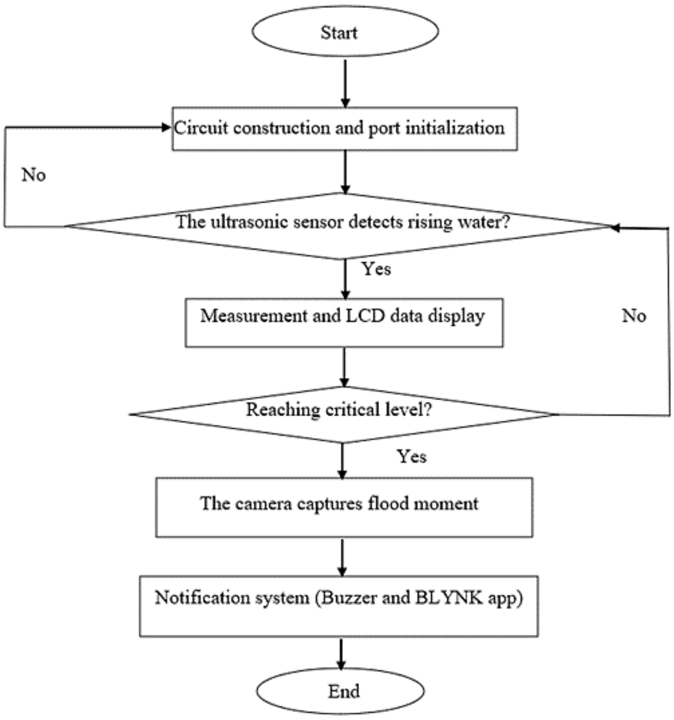

Figure 2: Project flow of IoT flood monitoring system

Hardware development is the most important phase of the project. There are three main components that are important for the development of this device. The ultrasonic sensor acts as an input element in this project. It is being used to measure the distance of flood water. Second is the Durian UNO microcontroller which acts as the heart of the project. All the programming is stored inside this microcontroller. Last is the buzzer and the camera which produce the output of this system. All these outputs will then be displayed on the Blynk application.

The HC-SR04 is a versatile ultrasonic sensor that can measure distances without human intervention in a number of settings. It can only measure distances between 2 and 80 cm to within 3 mm [6]. In this system, the ultrasonic sensor is used to detect the water level in an experimental tank. The distance is calculated with the basic speed, distance, and time formula which is:

$$\text{Distance} = \text{Speed} \times \text{Time} \quad (1)$$

The Durian UNO broad input power supply range (DC 3.7V to 12V). Unlike Arduino UNO, the Durian Uno has VCC and GND pins that make it easy to connect a module without a breadboard. Additionally, Durian UNO enables direct plug-and-play for servo motors. The DC current for 5V (VCC) up to 1A is capable of driving an MG995 servo motor and six SG90 micro servo motors concurrently without compromising stability [7]. This system uses a buzzer to alert the user when the flood water passes through the threshold height. The type of buzzer used is the Cylewet 5V active buzzer (CYT1036) [8]. The type of LCD used in this system is the 16 × 2 LCD. It has two rows with 16 characters on each row. This module includes the Hitachi HD44780 driver, which aids in the interface and communication with the microcontrollers [9]. The type of camera used in this system is the spy camera. Spy cameras are typically concealed as commonplace items in a workplace or residential environment. The modal of the camera used is the A9 spy camera with a WIFI connection to the cellphone.

2.3 Materials and method

The flood monitoring system project can be divided into two main parts which are hardware and software development. The hardware development part consists of all the hardware components used in this project. Some of the components are an ultrasonic sensor, microcontroller (Durian UNO), buzzer, battery/power supply, and LCD display 16 × 2. The software development includes Fritzing software to design the layout, Arduino IDE software for the programming, and the Blynk application to connect as an IoT platform.

2.3.1 Image quality improvements

Contrast enhancement, denoising, and sharpening techniques are used in this project to enhance the image quality produced by the camera installed in the system. The improvements in the produced images are compared in terms of the Mean-Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Signal-to-Noise Ratio (SNR) values. The built-in functions in MATLAB allow the execution of all these methods above.

2.43 System performance evaluation

2.4.1 System sensitivity and response time

The sensitivity of the ultrasonic sensor is tested by running the same experiment five times to see if there is any error occurred in detecting the level of water which has been set to 5 cm. Therefore, the experiment is repeated five times in a row to determine the sensitivity of the sensor.

To test the transmission time for the receiver to accept the message from the system, the experiment was repeated five times to record the time taken for the message to be received.

2.4.2 Imaging system quality assessment

One of an image's defining features is its image quality assessment (IQA). Picture quality assessment quantifies the decline in perceived image quality [10]. Degradation is typically determined in relation to a reference image that serves as an ideal standard.

The image quality performance metrics namely the MSE, PSNR, and SNR are used to test the quality of the image produced by the system's camera.

MSE is the most used estimator of image quality measurement metrics. It is a comprehensive reference metric and the values closest to zero is the better. The variance of the estimator and its bias are both integrated with the mean squared error [10]. The MSE is the variance of the estimator in the case of the unbiased estimator. It has the same units of measurement as the square of the quantity being computed same as a variance. MSE can be expressed as:

$$MSE = = \frac{1}{MN}\sum_{n=0}^{M}\sum_{m=1}^{N}[\hat{g}\,(n,m) - g(n,m)]^2 \qquad (2)$$

The peak signal-to-noise ratio (PSNR) is calculated by dividing maximum signal power by distortion noise power. These image comparisons are decibel-based. The logarithm term of the decibel scale is used to express PSNR due to the signals' broad dynamic range [10]. Based on signal quality, this dynamic range spans the highest to the lowest levels. Peak signal-to-noise ratio is generally used to assess lossy image compression codec reconstruction quality. The signal is the original data, whereas the noise is the transformation mistake. PSNR estimates reconstruction quality as seen by humans for compression codecs. PSNR can be expressed as:

$$PSNR = 10\ log_{10}(peakval^2)/MSE \quad (3)$$

Signal-to-noise ratios are usually better since noise only matters in relation to a signal [11]. A simple ratio (S/N) can also be converted to decibels (dB) using the formula below:

$$SNR\ (dB) = 20\ log10(S/N) \quad (4)$$

The image quality is said to be the best by having the highest PSNR value and the lowest MSE value.

3. Results and Discussion

The IoT flood monitoring system is expected to achieve all the objectives and requirements needed. At the end of this project, a group of data would be produced by the Blynk application. All the readings of the flood can be gained through this software where it will be easier for us to collect the results and make a conclusion.

3.1 System overview

The results of the system are determined by a few aspects involving system stability and the number of messages received by the user. It also includes a prototype design of the system to perform the real situation that may cause a flood to occur. The main objective of this prototype is to help a flood-prone area resident to evacuate from the area in the shortest period of time. Based on the prototype being designed, the tank is divided into two segments which represent land and a monsoon drain side by side. This example is taken from the residential area where the monsoon drain would overflow during the rainy season. In order to add water to the prototype design, water is manually poured into the tank using a large syringe. Figure 3 shows an image of the prototype design.

Figure 3: System top view

3.2 System performance

3.2.1 The sensitivity of the ultrasonic sensor in detecting the water level and the time taken to transmit the message from the system to the user through Blynk

The most important step in this system is to measure the distance of the flood water. This experiment is carried out in a small tank where the ultrasonic sensor is placed on the tank. The tank represents a monsoon drain in this experiment. The ultrasonic sensor would act as the reference point in this system where the initial value is zero (0). As the flood water increases and passes the threshold value, in our case, 5 cm, the buzzer would emit an alerting sound to alert the user. Moreover, the LCD would display if the water level is high or low. If the water level passes the threshold value of 5 cm, the LCD would display a ‘HIGH’ and if the water level does not pass the threshold value it would display as ‘LOW’.

The user would then receive a notification on the Blynk application, and he/she would be instructed to check the image of the flood.

The Blynk application is been used in this system to receive messages regarding the flood water level. The alerting message would be sent to the user's smartphone where the Blynk application is installed. As the water level in the monsoon drain increases to a dangerous level, the buzzer would trigger, allowing the Blynk application to alert its user and for checking the camera images showing the view of the scene. Table 1 shows the sensitivity of the ultrasonic sensor and also the time taken for the Blynk application to receive the notification from the system. The calibration of the ultrasonic sensor and the time taken for the Blynk application is checked by running the same experiment. This is done so to see if there is any error occurred in detecting the level of water which has been set to 5 cm and also if there was any error occurred by the Blynk application. Therefore, the experiment is repeated five times in a row simultaneously.

Table 1: The sensitivity of the ultrasonic sensor in detecting the water level and the time taken by the Blynk application to receive the notification from the system

No of experiments	Height of the water level detected by the ultrasonic sensor, (cm)	The time taken to transmit the message from the system to the user through Blynk, (s)
1	2.9	2.38
2	3.1	2.10
3	3.2	2.00
4	3.0	2.32
5	3.3	2.14

From Table 1, the reading tabulated for the sensitivity of the ultrasonic sensor in detecting the water level and the time taken by the Blynk application to receive the notification from the system. This experiment was repeated five times simultaneously to get the height of the water level detected by the ultrasonic sensor and the time taken for the Blynk to receive the notification from the system.

The line graph in Figure 4 shows how sensitive the ultrasonic is in detecting the water level is to the water and also how fast the Blynk application receives the message from the system. Each time the tank was filled with water, the ultrasonic sensor managed to sense the water level. We repeated the experiment five times, at each detection of signal (water level), the height of the water level would be measured from the ground level of the tank using a ruler. The result in Figure 4 shows fluctuation in the readings between 3 to 4 cm.

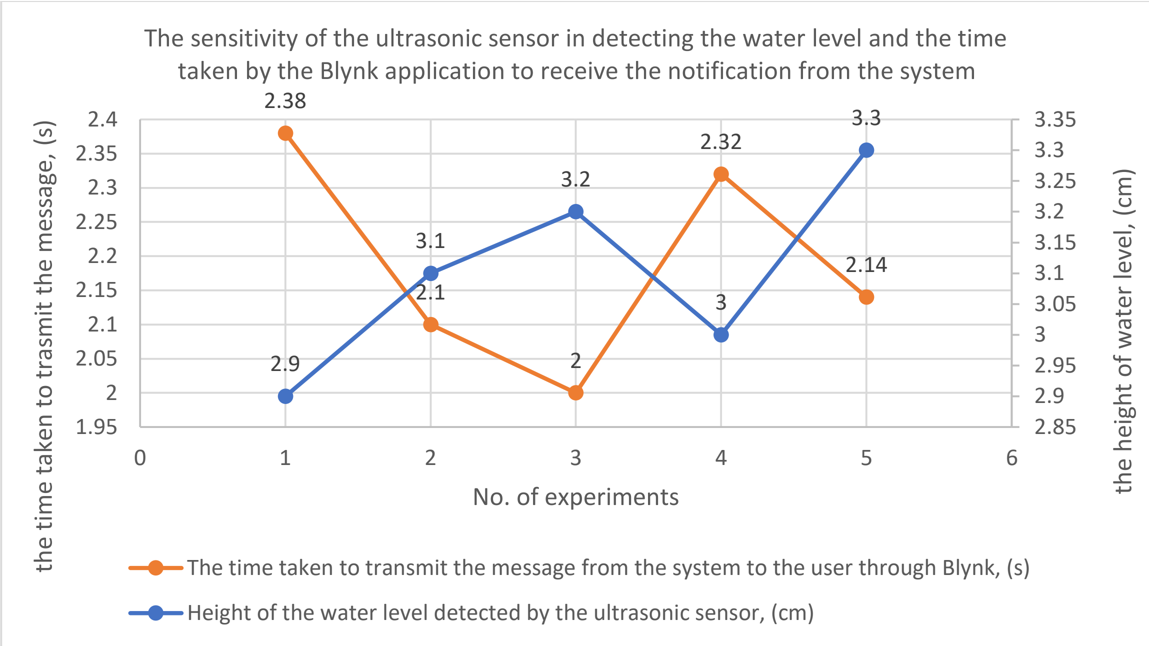

Figure 4: A line graph on the sensitivity of the ultrasonic sensor in detecting the water level and the time taken to transmit the message from the system to the user through Blynk

In conclusion, we can conclude that the height of the water level detected by the ultrasonic sensor has an average of 3.1 cm whereas the time taken to transmit the message from the system to the user through Blynk has an average reading of 2.19 s. The longest time taken for the Blynk to receive the message from the system is 2.38 s which can be due to the speed of the water being poured into the tank.

3.2.2 The mean (μ) and standard deviation (σ)

The mean (μ) and standard deviation (σ) of the sensitivity of the ultrasonic sensor in detecting the water level and the time taken to transmit the message from the system to the user through Blynk are calculated using the formulas shown in Eq. (5) and (6), respectively. The results are tabulated in Table 3 below.

$$Mean,\ \mu = \frac{\sum xi}{x} \tag{5}$$

$$Standard\ deviation,\ \sigma = \frac{\sqrt{(xi-\mu)^2}}{N} \tag{6}$$

Table 3: The mean, μ and standard deviation, σ

Type of experiments	Mean, μ	Standard deviation, σ
Detection sensitivity (cm)	3.10	0.158
System response time (s)	2.188	0.157

3.2.3 Image from the camera

There is also a camera installed to view the real-time image of the water in the tank. The camera is using an application called ‘Little Stars’ which is been installed in the user’s smartphone to view the situation of the monsoon drain anytime they want. Below is an example of the image captured by the camera of the tank image when the water level is high. The image produced is not that clear but the water level can still be seen. Figure 5 shows the image captured by the camera installed in the system.

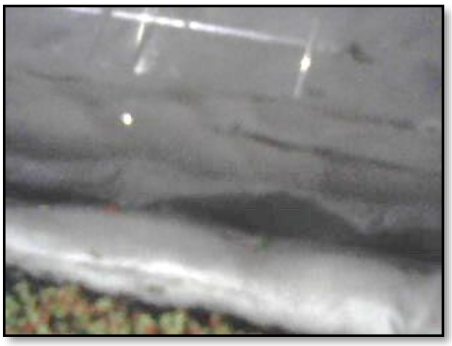

Figure 5: Image of the water level from the camera installed

To identify the MSE, SNR, and PSNR values of the image captured by the camera, the image is used to test its values through MATLAB to know how good the quality of the image is. Table 4 shows three different types of techniques used to improve the quality of the image that is produced by the camera installed in this prototype. The table is tabulated to show the PSNR SNR and MSE values of all those images using three different types of image enhancement techniques which are image sharpening, image denoising, and contrast enhancement techniques.

Table 4: Comparison of PSNR, SNR, and MSE of flood image with different techniques

Image Enhancement Technique	**Quality Measurement Parameters**		
	PSNR (dB)	**SNR (dB)**	**MSE (pixels)**
Contrast enhancement technique	15.4213	4.8548	1866.1462
Denoising technique	44.0308	33.4598	2.5704
Sharpening technique	29.6644	19.0934	70.2498

The best technique was chosen based on the highest PSNR value and the lowest MSE value. Based on the table above, it can be concluded that the best technique is the denoised technique with the highest PSNR value, which is 44.0308 dB, SNR of 33.4598 dB, and the lowest MSE value of 2.5704 pixels.

Image enhancement techniques are used to improve the quality of images captured by various devices, like the camera used in IoT flood monitoring systems. The development of these systems has been greatly facilitated by advancements in image processing and computer vision technologies, which allow for more accurate and efficient analysis of images. Image enhancement techniques such as denoising, sharpening, and contrast enhancement techniques are applied to the images captured by the cameras to remove noise, improve contrast, and reveal details that might be obscured by poor lighting or weather conditions. These enhanced images can then be used to detect and track changes in water levels, monitor the progress of floods, and provide real-time updates on conditions to disaster management agencies and communities. In this way, image enhancement techniques play a crucial role in the development of IoT flood monitoring systems and help to improve their effectiveness in providing early warning and responding to flooding events.

3.4 Output of the system

Figure 6 shows the notification received by the Blynk application from the system when the water level in the tank is detected to be high. The output of the system can be viewed from the Blynk application which states that the water level is high and it also alerts the user to view the camera images through their smartphone. The camera application is installed on the user's smartphone and can be viewed anytime.

Figure 6: Notification on Blynk

4. Conclusion

Based on the results of studies that have been done on the flood management system, all objectives of the project have been achieved regardless of any errors. Each part of this system functioned properly. The ultrasonic sensor was able to detect the distance of the water level perfectly which was set at a threshold value of 5 cm and the LCD display would display "HIGH" or "LOW" after detecting the level of flood water. If the water level passed the threshold value of 5 cm, the LCD would display a "HIGH" and if the water level in the tank was detected as less than 5 cm, it would display a "LOW". In our study, we found the detection sensitivity of 3.10±0.158 cm for activating the buzzer, which is used to alert its users. The camera installed would allow the users to view the real-time flood images through the camera application. The quality of the real-time image of the flood produced by the camera can be improved by installing a more expensive camera to improve image clarity. The IoT Blynk platform was able to send an alert message regarding the flood to the user's smartphone when the flood water level was detected as high. These functions provided a reliable delivery with a short response time of 2.19±0.157 s and produced a trustable output for its users. It was able to detect potential flooding conditions by the detection of water level using an ultrasonic sensor placed on a phantom environment with a rising water level. Last but not least, it brilliantly became a pre-warning system for flood safety by sending alerts to a smartphone through Blynk in a very short period of time.

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References

[1] Flood Management - Programme and Activities. (2017, May 2). Official Portal for Department of Irrigation and Drainage Ministry of Natural Resources, Environment and Climate Change. Available: https://www.water.gov.my/index.php/pages/view/419. [Accessed Jan. 2, 2023]

[2] Floods claim 54 lives so far, two still unaccounted for - Bukit Aman. (May 1, 2022). BERNAMA. Available: https://www.bernama.com/en/general/news_disaster.php?id=2040627. [Accessed Jan. 2, 2023]

[3] Reuters, S. by. (January 3, 2022). Malaysia floods hit seven states forcing thousands to evacuate. CNN. Available: https://edition.cnn.com/2022/01/02/asia/malaysia-floods-evacuation-intl-hnk/index.html. [March 31, 2022]

[4] S. I. Azid, B. N. Sharma, K. Raghuwaiya, A. Chand, S. Prasad and A Jacquier, "SMS based flood monitoring and early warning system," ARPN Journal of Engineering and Applied Sciences, 10(15), 6387-6391, 2015. [Online]. Available: researchgate, https://www.researchgate.net/profile/BibhyaSharma/publication/283101853_SMS_based_flood_monitoring_and_early_warning_system/links/5c3bfd3892851c22a3735e66/SMS-based-flood-monitoring-and-early-warning-system.pdf?origin=publication_detail. [June7, 2022]

[5] F. Curumtally, R. Khoodeeram, 'Real Time Flood Monitoring and prevention using IOT sensors in developing countries," in 2021 IST-Africa Conference (IST-Africa), 2021. pp. 1-9. Available: IEEE Xplore, https://ieeexplore.ieee.org/document/9577002. [Accessed June 7, 2022]

[6] D. Lost, What is an ultrasonic sensor?, Oct. 7, 2019. [Online]. Available: Fierce Electronics, https://www.fierceelectronics.com/sensors/what-ultrasonic-sensor. [Accessed June 7, 2022]

[7] Durian Uno - enhancement of Arduino Uno for IOT Project Education. [Online]. Available: MYBOTIC, https://www.mybotic.com.my/durian-uno-enhancement-of-arduino-uno-for-iotproject. [Accessed Nov. 27, 2022]

[8] Buzzer: Working, types, circuit, Advantages & Disadvantages, July 26, 2021. [Online]. Available: ElProCus, https://www.elprocus.com/buzzer-working-applications/. [Assessed June 7, 2022]

[9] Standard LCD 16x2 display. [Online]. Available: https://www.thingbits.in/products/standard-lcd-16x2-display. [Accessed June 7, 2022]

[10] U. Sara, M. Akter M. And M. S. Uddin, "Image quality assessment through FSIM, SSIM, MSE and PSNR—a comparative study," Journal of Computer and Communications, vol. 07, no. 03, pp. 8–18, 2019, doi: 10.4236/jcc.2019.73002

[11] Noise in photographic images. [Online]. Available: Imatest, https://www.imatest.com/docs/noise [Accessed Dec. 29, 2022]