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Development of Underwater Data Capturing Vehicle Platform

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Abstract

The invention of the underwater data capture vehicle platform marks a significant improvement in underwater research technology. The project sought to address issues associated with underwater data collection, such as image quality, water quality testing, and search and rescue operations. Using IoT technologies and modern equipment, the platform provides a full solution for monitoring and evaluating underwater environments. The project aim is to construct a moving platform with underwater data measurement equipment for underwater object recognition studies. The study also focuses on the remotely controlled conveyance of underwater research items. The project objectives include creating a moving platform and its measuring equipment arrangement, constructing an underwater data collection vehicle platform with an IoT application, and evaluating the platforms operation and data gathering procedures. This project was successful in designing and developing an underwater data gathering vehicle platform with Internet of Things (IoT) capabilities. The platform exhibited its capacity to float well with a weight on its surface, and the crane worked well for lowering research equipment and cameras underwater. Turbidity and underwater depth distance data were obtained at various depths and weather conditions, yielding vital information on water quality. Underwater images captured at different depths were successful and can further help to comprehend underwater conditions. Overall, this project met its goals and provided a complete solution for viewing and analyzing underwater conditions using current technologies and IoT.

1. Introduction

Underwater data collection has been used in aquatic vision research. There is a growing use of new technology to improve life safety, and autonomous technology is no exception [1]. Underwater image processing is a challenging field because of the physical properties of such an environment. Researchers engaging in underwater research face the challenges of light absorption and diffusion effects on underwater imaging [2]. Water quality testing is a critical component of environmental monitoring. When water quality is bad, it has an impact not just on aquatic life but also on the surrounding ecology. There are various parameters that affect the quality of water in the environment. These properties can be physical, chemical, or biological factors. Physical properties of water quality include temperature and turbidity [3]. The water quality may also be studied using

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the water PH, acid in the water, alkali, oxygen, and chlorine. There are three water quality parameters that help to measure the quality of water, which include physical parameters, chemical parameters, and biological parameters [4]. Underwater technology may also be utilized to aid in search and rescue operations (SAR). Underwater search and recovery specifically are the process of locating and recovering victims or objects lost underwater by divers, remotely operated vehicles and/or electronic equipment on surface vessels [5]. The project sought to address issues associated with underwater data collection, such as image quality, water quality testing, and search and rescue operations. Using IoT technologies and modern equipment, the platform provides a full solution for monitoring and evaluating underwater environments. The project aim is to construct a moving platform with underwater data measurement equipment for underwater object recognition studies. The study also focuses on the remotely controlled conveyance of underwater research items. The project objectives include creating a moving platform and its measuring equipment arrangement, constructing an underwater data collection vehicle platform with an IoT application, and evaluating the platforms operation and data gathering procedures.

2. Literature Review

Pontoon boats have large decks on top of long tubes called pontoons. They sit above the water, are spacious, provide a smooth ride, and have good safety ratings. Pontoons are primarily designed for freshwater use [6]. Their big decks are great for mingling, and you can participate in hobbies such as waterskiing and fishing. If you're searching for a fun and spacious boat, a pontoon boat can be the best option for your family. There are two primary types of Pontoon designs used for current commercial Pontoon boats. The first type is the foam filled (U) shaped Pontoon, another is the round baffled single chambered Pontoon, and there is also the single round Pontoon type with several airtight individual compartments [7]. Table 1 shows the comparison of pontoon boat design.

Table 1 *Comparison of Pontoon boat design [7, 8]*

Type	Details	Advantages	Disadvantages
Flat bottom [7]	Typically found on bay boats, made from aluminum, and specialized for shallow water with features such as a raised bow, ample deck space, and a cockpit.	-Operates best in calm bodies of water. -Lightweight and very stable. -Easily maneuverable.	Not allow movement at very high speed.
U shaped bottom [8]	U-shaped pontoons provide more volume and carrying capacity. Higher and drier riding. The U-shape keeps water from collecting on top of the pontoon and dragging it down.	-Primarily the inherent safety of a redundant flotation system that it provides. -For the U-shaped pontoons are inherently easier to produce and manufacture.	-Generally, narrow in width. -Nearly impossible to repair effectively and poses a serious problem.

Based on the design the suitable type of Pontoon boat for this study is by using U shaped design because it provides more volume and carrying capacity. Moreover, it has hole at the middle of boat, which is suitable to install the crane and as location to lower the research equipment panel.

There are many different uses for gantry cranes, which are strong and adaptable cranes. They are an important component of the global economy and a necessary tool for many different sectors. In many industrial applications, the operation of the crane system depends on a skilled operator using visual feedback. Control of an overhead gantry crane is complicated by the need to damp the swinging of the load [9]. In the construction sector, tower cranes are an essential instrument. Assisting with the timely and cost-effective completion of building projects, they enable workers to lift and move bulky materials with efficiency and safety. Tower cranes are usually used for lifting the prefabricated components from a trailer onto the structure under construction, and the weight and volume of individual components cannot be changed and adjusted [10]. Table 2 shows the comparison between gantry crane and tower crane.

Table 2 *Comparison between gantry crane and tower crane [9, 10]*

Type	Features	Advantages	Disadvantages
Gantry Crane [9]	**Structure:** Two freestanding legs support a horizontal bridge beam. **Mobility:** Able to move via a rail system or track **Application:** Frequently found in outdoor locations like ports and factories	-Simple to personalize -Total mobility	-Permanent installation may be necessary -A large space is necessary
Tower Crane [10]	**Structure:** A horizontal jib is supported by a vertical mast. **Mobility:** Usually, stationary **Application:** Often used in places where great lifting heights are needed, such as building sites	-A large lifting capability -Mobility in difficult terrain	Setup is complicated - Unable to be mobilized

Based on the gantry crane structure it is suitable to be used in this study because the structure is balance if installed on the platform. It is expected to how less effect on the platform stability on the water surface. Moreover, it has the advantages of simplicity to customize and has total mobility. Table 3 shows the comparison between Insta360 Ace Pro camera and SJCAM 4000 camera.

Table 3 *Comparison between Insta360 Ace Pro Camera and SJCAM 4000 camera [11, 12]*

Camera Type	Features	Advantages	Disadvantages
SJ CAM 4000 [12]	**Video:** Up to 4K at 30fps **Camera:** 16 MP **Wi-Fi:** 2.4GHz, 5GHz **Price range:** RM 373.00	-Dual Screen Design -User-friendly Interface -Mobile App Support -Waterproof	-Short battery life -Basic audio quality -Limited low-light performance
Insta360 Ace [11]	**Video:** Up to 8K at 30fps **Camera:** 48MP **Wi-Fi:** 2.4GHz, 5GHz **Price range:** RM 2099.00	-Flip up screen -Quick charge -Strong low-light performance -In ideal conditions, the effective Bluetooth range of Insta360 cameras is 33 feet (10 meters). -Without having to press the shutter button to confirm your connection, your phone may instantly connect to the camera within the camera's Bluetooth range. -Can connect to Ista360 application for IoT application and waterproof	-Mounting clip can be a bit fussy -No 10-bit video option

Based on the comparison between the SJCAM 4000 and Insta360 Ace Pro cameras, device suitable for this study is the SJCAM 4000 camera. It provides waterproof body which is suitable to capture underwater images. Furthermore, it can be connected to phone using application, which is suitable for IoT implementation. The SJCAM 4000 price range is lower than the Insta360 Ace Pro camera. Table 4 presents the difference between 3-Channel and 4-Channel RC.

Table 4 *Differences between 3-Channel and 4-Channel RC [13, 14]*

Channel type	Features	Advantages	Disadvantages
3-Channel Remote control [13]	**Controllable Function:** Throttle, Steering, Elevator, and Ailerons **Versality:** Basic control vehicle	-Affordability -Portability -Ease of use -Connection range up to 200 meters	-Limited functionality -Limited control -Limited customization
4-Channel Remote control [14]	**Controllable Function:** Throttle, Steering, Elevator, Ailerons, Retracts, Landing gear and Flaps **Versality:** Able to operate a greater range of remote-control vehicles, including those with more sophisticated features or intricate maneuvers	-More control -More functionality -Can customize the button -Connection range up to 200 meters	-Higher cost -More complex -Less portable

The suitable remote-control for this study is the 4-channel remote control. It is because it can control more functions using one remote control. Moreover, the user can customize the functions for this remote control based on the user need. Furthermore, the connection between transmitter and receiver is up to 200 meters connection signal. Table 5 presents the type of turbidity sensor.

Table 5 *Types of turbidity sensor [15, 16, 17]*

Type	Details	Advantages	Disadvantages
Gravity Arduino turbidity sensor [15]	Detects water quality by measuring the levels of turbidity, or the opaqueness. It uses light to detect suspended particles in water by measuring the light transmittance and scattering rate, which changes with the amount of total suspended solids (TSS) in water.	-The sensor Is simple to use and may be linked to an Arduino board. -It can produce both analogue and digital signals. -When using a digital signal, the threshold can be adjusted.	-The top of the probe is not waterproof.
Nephelo-metric turbidity sensors [16]	They measure how light energy scatters in a liquid.	-They are precise. -Nephelometric turbidity sensors are easy to use and produce data quickly. -They are cost-effective and have a good price-performance ratio.	-The nephelometric turbidity sensors are readily damaged. -They demand a lot of electricity. -They are not appropriate for greater concentrations.
Absorption turbidity sensors [17]	As a light source, they employ an LED (Light Emitting Diode) that produces light at a given wavelength or within a certain wavelength range.	-Highly accurate. -They are suitable for high concentrations.	-More expensive than other types of turbidity sensors. -More complex to use and require more maintenance.

The turbidity sensor that is suitable for this study is the gravity Arduino turbidity sensor because the sensor is simple to use and easy to link with Arduino board. The sensor can also produce both analog and digital signals. The disadvantage for this sensor is at the top probe is not waterproof and it can be solved by using casing. Table 6 presents the differences between distance measurement sensor types.

Table 6 *Differences between distance measurement sensor types [18, 19,20]*

Type	Details	Advantages	Disadvantages
Active sonar [18]	Active sonar uses a sound transmitter (or projector) and a receiver. It generates a sound pulse and then listens for the pulse's reflections/echoes.	Speed communication of transmit and receive the signal. 80% accurate to detect underwater items and mapping.	-Harmful to marine life. -Multiple transmission and reflection.
Passive sonar [19]	Passive sonar listens without transmitting. Also, can encompass virtually any analytical technique involving remotely generated sound.	Frequencies used in sonar systems vary from very low.	-The sonar waves interfere with whales, dolphins, seals, and turtles. -Makes a lot of noise.
Ultrasonic sensor [20]	It generates an ultrasonic at 40 000 Hz that travels through the air and returns to the module if it encounters an item or impediment along the way. The distance may be calculated using the travel time and sound speed.	-Ultrasonic sensors can estimate distance without requiring physical contact, making them excellent for situations where the target is delicate or unsafe to approach. -These sensors can work in hostile situations, such as dusty, smoky, or wet circumstances, where optical sensors may fail.	-Ultrasonic sensors typically have a restricted range of only a few meters, making them unsuitable for long-distance measurements. -Sound speed changes with temperature and humidity, affecting measuring accuracy.

The suitable distance measurement sensor for this study is by using the ultrasonic sonic sensor. It generates an ultrasonic at 40 000 Hz that travels through the air and returns to the module if it encounters an item or impediment along the way. The distance may be calculated using the travel time and sound speed.

3. Methodology

3.1 Underwater Data Capture Vehicle Platform System

The user configures research equipment, including a camera, lighting, turbidity sensor, ultrasonic sensor microcontroller, remote control, Wi-Fi connection, vehicle receiver, and power supply. Fig. 1 shows the underwater data capturing vehicle platform system flowchart. The control system is initiated in Process A, followed by Process C, which connects the camera to the SJCAM ZONE application and the turbidity and ultrasonic sensors to the Blynk application. The vehicle platform is placed in water, lowered using a crane to a depth of 10 cm, and data is captured in Process F. The turbidity sensor measures the water's level, and the data is stored in the Blynk Cloud storage. The data is then retrieved at a depth of 30 cm, and the user returns to their location using remote control. The battery status is checked, and the battery is stopped if full. More, (a), (b), (c),(d), (e), (f) and (g) is the label of the flow chart process.

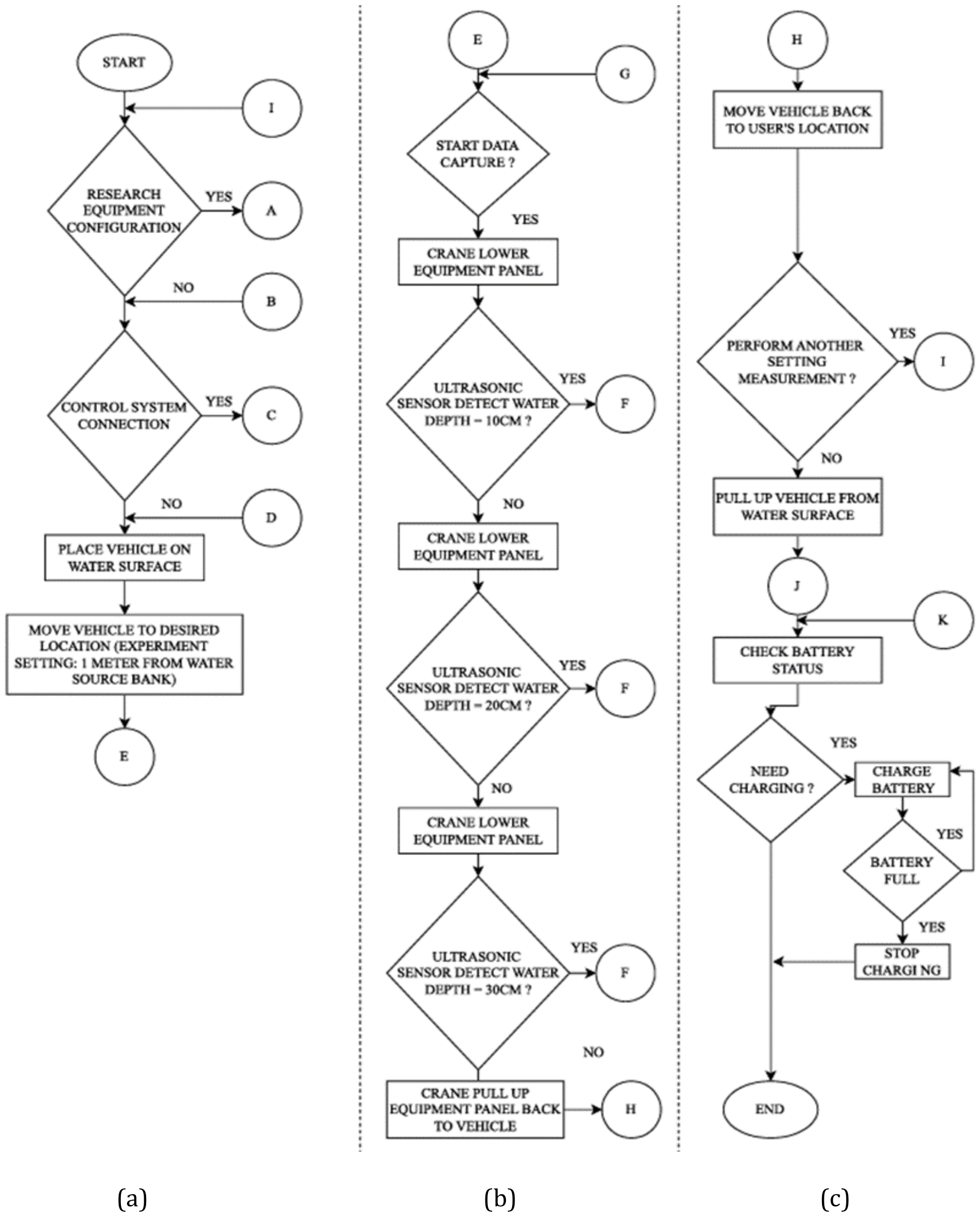
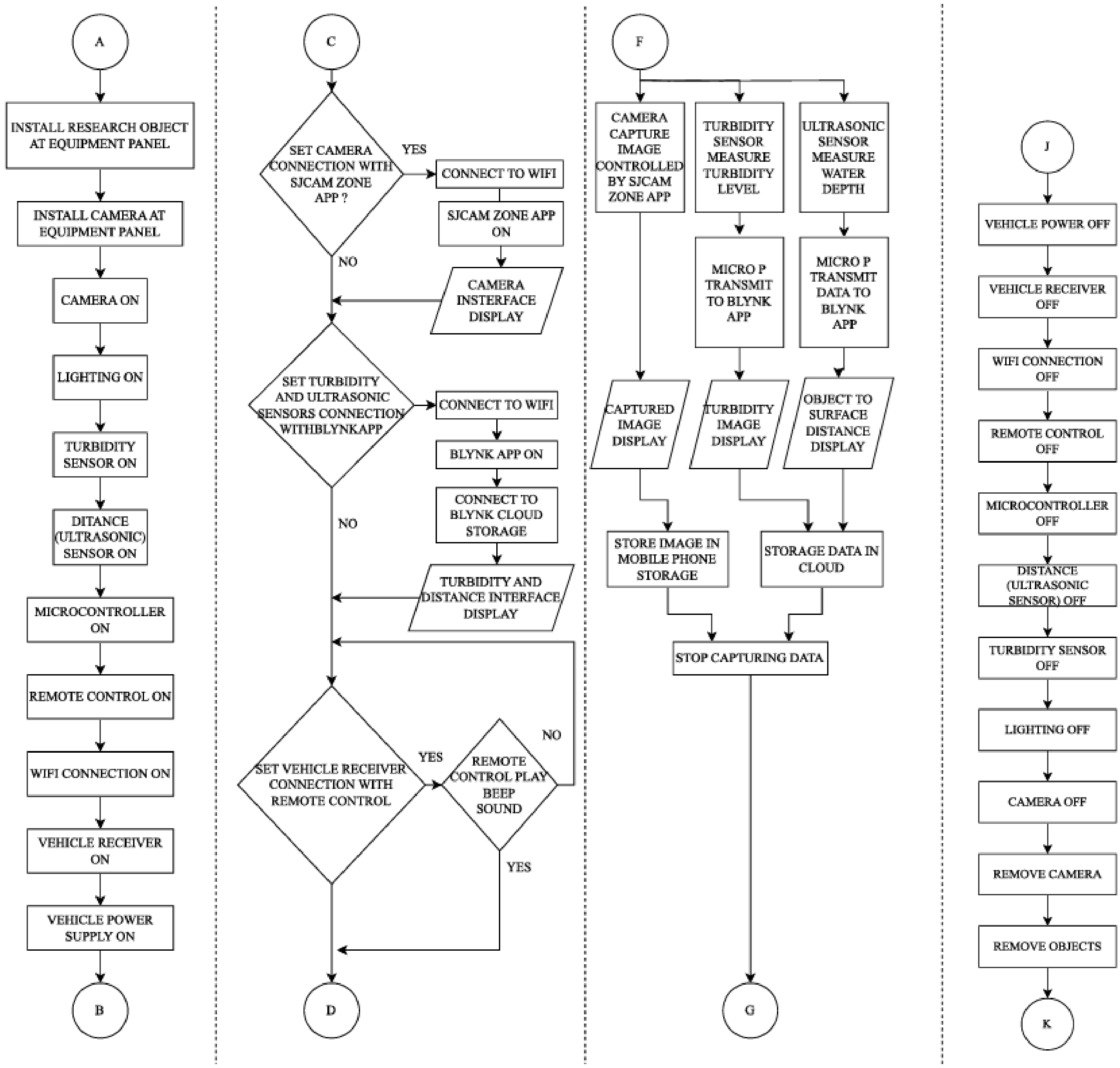


Fig. 1 *Underwater data capturing vehicle platform system flowchart*

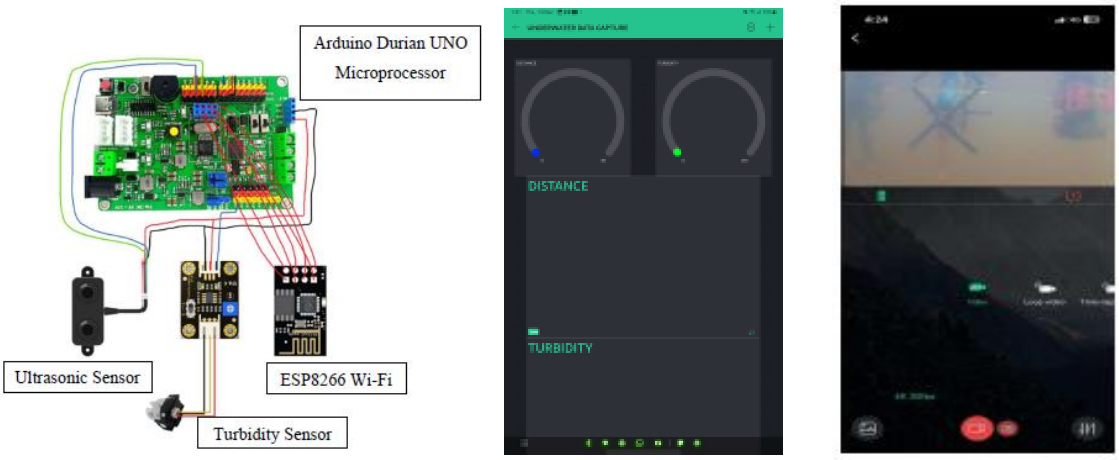


(d) (e) (f) (g)

Fig. 1 *Underwater data capturing vehicle platform system flowchart(continued)*

3.2 Project software requirements

The software requirements will discuss the application to be utilized in this study, which is the Blynk application and the SJCAM ZONE application. The Blynk application is utilized in this project. The Wi-Fi module from the Arduino Durian UNO microprocessor will be connected with the Blynk application. Fig. 2(a) shows the connection diagram of the Arduino Durian UNO. The module with 6 pins on the Arduino Durian UNO microprocessor is the Wi-Fi module that will be connected with the Blynk application when the Wi-Fi is turned on. Application design is also important to support data collected from underwater. This application is suitable for this project and the interface design will display the data necessary for this study, such as real-time images, turbidity on the water, and the distance of the object reduced, and the depth level established. The Blynk application will be utilized in this investigation. Fig. 2(b) shows the Blynk application interface. Moreover, this application is also readily developed in compliance with this project. Real-time images can be observed by using camera applications, which is the SJCAM ZONE application that can be connected with the SJCAM 4000 camera. Fig. 2(c) shows the SJCAM ZONE application interface.



(a) (b) (c)

Fig. 2 *(a)The connection with Arduino Durian UNO diagram, (b) Blynk application interface, (c) SJCAM ZONE application interface*

3.3 Vehicle platform design

It is important to maintain platform stability for the weight when placed on the water surface. Fig. 3 shows the design of the vehicle platform with attached gantry crane to collect underwater data in accordance with the study's requirements. The gantry crane construction is used on the middle platform to increase platform stability. The equipment panel will be attached to the crane through the hole at the center of the vehicle platform.

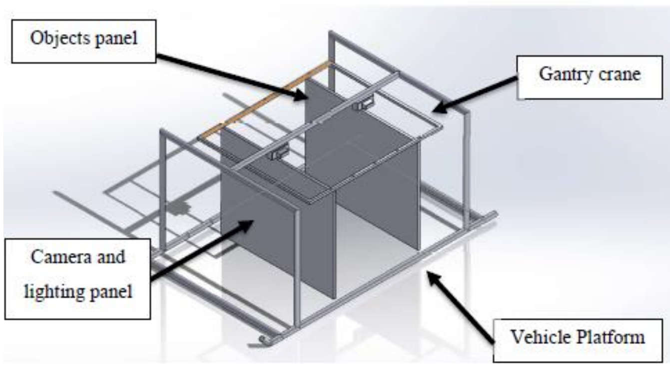


Fig. 3 *Vehicle platform design*

3.4 Turbidity measurement

The process of collecting underwater data by utilizing a turbidity sensor equipped with a turbidity reading in nephelometric turbidity units (NTU). In addition, identify the working of turbidity, the sensor operates on the principle that when the light is passed through a sample of water, the amount of light transmitted through the sample is dependent on the amount of soil in the water [21].

$$NTU = -1120.4 \text{ x } (volt)^2 + 5742.3 \text{ x } volt - 4352.9 \quad (1)$$

3.5 Object to surface distance measurement

In this project, the ultrasonic sensor is used for determining underwater distances. It can estimate the distance of an item that goes beneath water. The distance is calculated according to the ultrasonic sensor datasheet [22].

$$\textit{Calculation of distance: distance} = \textit{speed of sound} \text{ x } \textit{duration} = 0.0343 \text{ x } (\textit{duration}/2) \quad (2)$$

4. Results and Discussion

4.1 Design development analysis

The analysis of the developed of underwater data capturing vehicle equipped with Internet of Thing (IoT) application. The underwater data capturing vehicle platform design used SolidWorks software to develop the design based on the need of this study. This vehicle platform fitted with a gantry crane as a tool for lowering research equipment underwater to substitute human labor and operated by a remote-control device. This design was completed and effectively developed with this software. Fig. 4 shows the developed underwater data capturing vehicle platform.

Fig. 4 *The underwater data capturing vehicle platform*

4.2 Performance Assessment and Data Acquisition Analysis

This sub chapter will go over performance evaluation and data collection. The rating is based on the platform's durability above the surface of the water and its capacity to carry research items. The data is then analyzed depending on the readings from the sensor, which has been configured to capture real-time underwater data.

4.2.1 Vehicle Platform Performance Analysis

The functional assessment is important because it impacts the quality of the data obtained. In this experiment the functions of each remote-control component on platform, which is the motor for movement and rudder for turn left and right on the surface of the water is tested. The crane for lowering down and up the camera and research objects in the water during the data collection at Tasik Kemajuan UTHM is also tested. The first testing is to assess the platform floating ability. Fig. 5 shows the vehicle platform with research equipments can float successfully on the water surface.

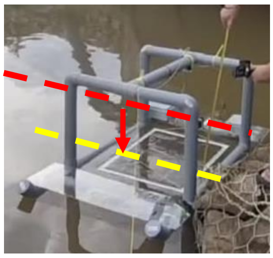
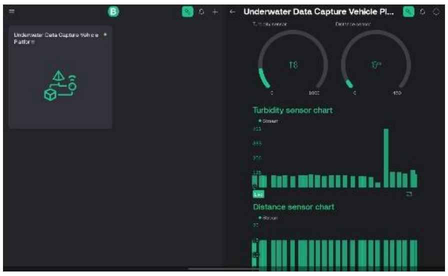
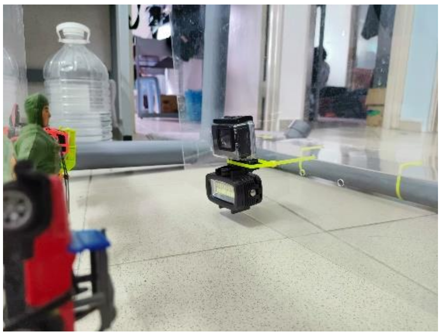
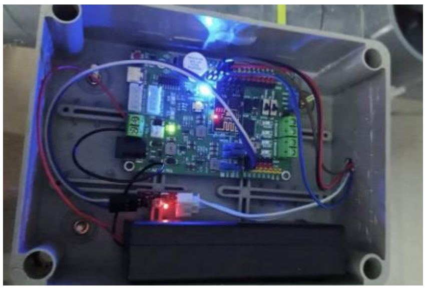
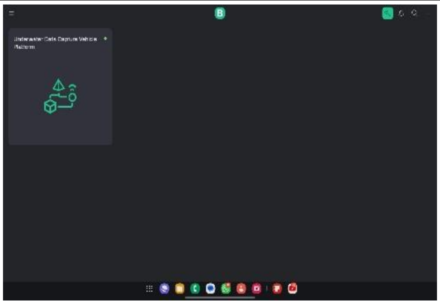
Fig. 5 *Data capturing vehicle platform with research equipment floating on the water surface*

The next test is the functionality assessment, where the capabilities of the twin engine and rudder to move the platform forward and backward in addition to the left and right as well as sensor reading and display functionality lighting functionality and IoT functionality were investigated. Table 7 shows the developed vehicle operations.

Table 7 *Developed vehicle platform operation*

Images		Conditions
	 Starting point image	The platform starts at 0 cm to move on the water surface. (Note: red dotted line in starting point)
 Starting point image	 Move forward image	The platform was moved 143 cm forward (Note: red dotted line in starting point, yellow dotted line represents new location)
 Starting point image	 45º turning image	The platform was turning 45º to the right (Note: red dotted line in starting point, yellow dotted line represents new location)
 45º turning image	 Reverse image	The platform was in reverse condition after turning 45º to the right (Note: red dotted line in starting point, yellow dotted line represents new location)
 Crane at 0 cm depth	 Crane lowered at 10 cm depth	The crane lowered the research object and camera until 10 cm depth. (Note: red dotted line in starting point, yellow dotted line represents new lowered crane point)

Table 7 *Developed vehicle platform operation* (continued).

 Crane at 0 cm depth	 Crane lowered at 20 cm depth	The crane lowered the research object and camera until 20 cm depth. (Note: red dotted line in starting point, yellow dotted line represents new lowered crane point)
 Crane at 0 cm depth	 Crane lowered at 30 cm depth	The crane lowered the research object and camera until 30 cm depth. (Note: red dotted line in starting point, yellow dotted line represents new lowered crane point)
 No reading on distance sensor and turbidity sensor (before)	 Reading value on distance sensor and turbidity sensor (after)	**Sensors:** The distance sensor and turbidity sensor (before and after) readings
 The lighting is turned OFF	 The lighting is turned ON	The lighting supports for the camera before turning ON and turning OFF
 Wi-Fi receiver and trasnmitter turning ON	 Blynk application is in online mode after connected with Wi-Fi	Wi-fi receiver and transmitter turning ON and connected with the Blynk application in the phone

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4.2.2 Turbidity Sample Analysis

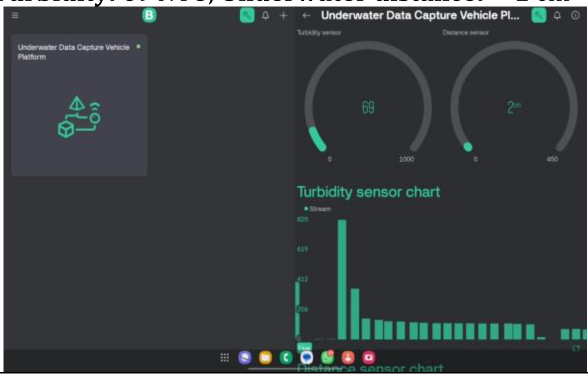
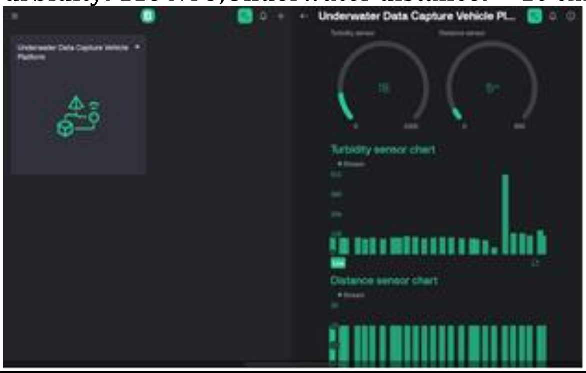
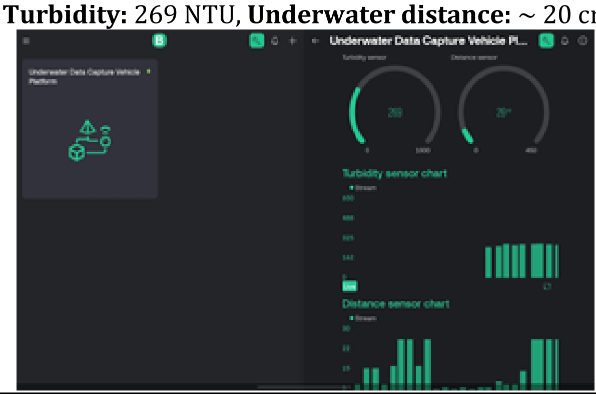
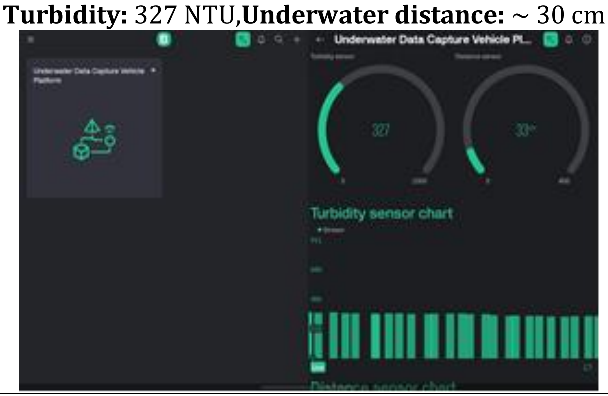
This turbidity data was gathered under various weather conditions and underwater distances. A bottle was used to collect water samples, which were then put in a 30 cm high container. In addition, the ultrasonic sensor is put on top of the bottle, while the turbidity sensor is placed in the water, and readings are obtained according to the depth of 10 cm, 20 cm, and 30 cm, as well as the water turbidity reading according to the turbidity sensor reading. The underwater distance was set at 10 cm, 20 cm, and 30 cm. Table 8 shows the turbidity of the "Tasik Kemajuan" lake UTHM.

Table 8 *Turbidity data for "Tasik Kemajuan" lake UTHM*

Date	Time	Weather & Condition	Turbidity sensor	Underwater distance
11/5/2024	11:45am	Sunny / 35°C	11 NTU	10 cm
			12 NTU	20 cm
			12 NTU	30 cm
12/5/2024	4:30pm	Cloudy / 25°C	24 NTU	10 cm
			77 NTU	20 cm
			85 NTU	30 cm
17/5/2024	5:30pm	Rainy / 24°C	174 NTU	10 cm
			370 NTU	20 cm
			429 NTU	30 cm

4.2.3 Underwater Turbidity Analysis

Table 9 *Underwater turbidity results*

Turbidity: 69 NTU, **Underwater distance:** ~ 2 cm 	**Turbidity:** 118 NTU,**Underwater distance:** ~ 10 cm 
Turbidity: 269 NTU, **Underwater distance:** ~ 20 cm 	**Turbidity:** 327 NTU,**Underwater distance:** ~ 30 cm 

This underwater turbidity analysis will explain the result collection of real-time data, taken from vehicle platform. The underwater data capturing vehicle platform was turned on and the conditions of the connection and measurement tools such as ultrasonic sensors and turbidity connection with the Blynk application, as well camera connection to SJCAM ZONE application are checked before lowered to the surface of the water. Using the remote-control crane trigger, measurement equipment and panels objects are lowered down to depths of 10 cm, 20 cm, and 30 cm. At that depth, the images, distance, and turbidity of the water were recorded. The turbidity levels recorded in this experiment were taken after the rain, which affected the water turbidity at each water depth set in this experiment. Table 9 shows the underwater turbidity levels during the experiment was recorded on 22 May 2024, 4:30pm, cloudy / 27°C.

4.2.4 Underwater Images Capture Analysis

Feature images captured underwater at various levels during the experiment. There are three distinct water depths, which are 10 cm, 20 cm, and 30 cm. also the distance objects image to camera is 20 cm length. The underwater images captured are shown in Fig. 6.

(a) 10 cm depth (b) 20 cm depth (c) 30 cm depth

Fig. 6 *Underwater image captured*

5. Conclusion

As a conclusion, the invention of the underwater data capture vehicle platform marks a significant improvement in underwater research technology. The project sought to address issues associated with underwater data collecting, such as image quality, water quality testing, and search and rescue operations. Using IoT technologies and modern equipment, the platform provides a full solution for monitoring and evaluating underwater surroundings. The project aim is to construct a moving platform with underwater data measurement equipment for underwater object recognition study. The study also focuses on remotely controlled conveyance of underwater research items. The project's objectives include creating a moving platform and its measuring equipment arrangement, constructing an underwater data collecting vehicle platform with an IoT application, and evaluating the platform's operation and data gathering procedure. This project was successful in designing and developing an underwater data gathering vehicle platform with Internet of Things (IoT) capabilities. The platform exhibited its capacity to float well with a weight on its surface, and the crane worked well for lowering research equipment and cameras underwater. Turbidity and underwater depth distance data was obtained at various depths and weather circumstances, yielding vital information on water quality. Underwater images captured at different depths and underwater conditions were successful. Overall, this project met its goals and provided a complete solution for viewing and analyzing underwater conditions utilizing current technologies and IoT.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: Hazli Roslan, Siti Zarina Mohd Muji; data collection: Muhamad Nazmi Afzan John Aqmal; analysis and interpretation of results: Muhamad Nazmi Afzan John Aqmal, Suhaila Sari, Nik Shahidah Afifi Md Taujuddin; draft manuscript preparation: Muhamad Nazmi Afzan John Aqmal, Suhaila Sari. All authors reviewed the results and approved the final version of the manuscript.

References

[1] Murphy, AJ., Landamore, MJ. & Birmingham RW (2008) The role of autonomous underwater vehicles for marine search and rescue operations, *Underwater Technology*, 27(4), 195–205, https://doi.org/10.3723/ut.27.195.

[2] Abdul Ghani, A. S. & Mat Isa, N. A. (2015) Underwater image quality enhancement through integrated color model with Rayleigh distribution, *Applied Soft Computing*, 27, 219–230 https://doi.org/10.1016/j.asoc.2014.11.020.

[3] Fondriest Environmental Learning Center. (2024, June 12). Water quality. https://www.fondriest.com/environmental-measurements/parameters/water-quality.

[4] Dominic O'Donnell (2021, September 20). Three main types of water quality parameters explained. Sensorex Liquid Analysis Technology. https://sensorex.com/three-main-types-of-water-quality-parameters

[5] Deep Trekker. Underwater search and recovery: Patterns you should know. Deep Trekker. Retrieved June 12, 2024, from https://www.deeptrekker.com/news/underwater-search-rescue-patterns-should-know.

[6] Progressive. What is a Pontoon Boat? Retrieved June 12, 2024, from https://www.progressive.com/answers/what-is-a-pontoon-boat/

[7] Scott Reynolds. (2016, April0 21). The 3 basic shapes of Pontoons designs - Their Pros & Cons. Pontoon Depot. https://pontoon-depot.com/blogs/news/115890820-the-3-basic-shapes-of-pontoons-designs-their-pros-cons

[8] Nove Sea. The advantages and disadvantages of Flat-bottom boats. Retrieved June 12, 2024, from https://www.novesea.com/blog/post/the-advantages-and-disadvantages-of-flat-bottom-boats.html

[9] Abduljabbar, B. H., Billingsley, J. & Wen, P. (2021) A pragmatic controller for a gantry crane. *Journal of Physics. Conference series*, 1780(1), 12007, https://doi.org/10.1088/1742-6596/1780/1/012007.

[10] Zhou, C., Dai, F., Xiao, Z. & Liu, W. (2023) Location optimization of tower cranes on high-rise modular housing projects, *Buildings*, 13(1), 115, https://doi.org/10.3390/buildings13010115.

[11] SJCAM. *SJCAM SJ4000 Dual Screen Wifi Action Camera – SJCAM*. Retrieved June 12, 2024, from https://shop.sjcam.com/product/cameras/action-cameras/sj4000-dual-screen/?_gl=1*zzttkc*_up*MQ.&gclid=Cj0KCQjwmMayBhDuARIsAM9HM8cUB372UE1i8NgGWrzGSCZzL2M1oJT2mxgmSMY3jHcq-oXramdwQhIaAkVjEALw_wcB

[12] Insta360. *Insta360 Ace Pro Camera*. Retrieved June 12, 2024, from https://www.myinsta360.com/products/insta360-ace-pro-camera

[13] Kyle Hilson (2023, November 13). Exploring the mechanics and benefits of 3 Channel RC airplanes. Swell RC. https://www.swellrc.com/3-channel-rc-airplane

[14] Pete. *Radio control functions explained*. RC Airplane World. Retrieved June 12, 2024, from https://www.rc-airplane-world.com/radio-control-functions.html

[15] DFROBOT. *Turbidity_sensor_SKU__SEN0189*. Retrieved June 12, 2024, from https://wiki.dfrobot.com/Turbidity_sensor_SKU__SEN0189

[16] Metzger, M., Konrad, A., Blendinger, F., Modler, A., Meixner, A.J., Bucher, V., & Brecht, M. (2018) Low-Cost GRIN-Lens-Based Nephelometric Turbidity Sensing in the range of 0.1–1000 NTU. *Sensors*, 18(4), 1115, https://doi.org/10.3390/s18041115.

[17] Dominic O'Donnell (2021, September 13). Understanding the science behind Turbidity Sensors and how they work. Sensorex. https://sensorex.com/understanding-the-science-behind-turbidity-sensors-and-how-they-work/

[18] Susie Maestre (2022, April 7). What is the difference between sonar and ultrasonic sensors? CircuitBread, https://www.circuitbread.com/ee-faq/what-is-the-difference-between-sonar-and-ultrasonic-sensors

[19] RF Wireless World. *Advantages of SONAR| Disadvantages of SONAR*. Retrieved June 12, 2024, from https://www.rfwireless-world.com/Terminology/Advantages-and-Disadvantages-of-SONAR.html

[20] Dejan. *Ultrasonic Sensor HC-SR04 and Arduino – Complete Guide*. How to Mechatronics. Retrieved June 12, 2024, from https://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/

[21] *DIY Turbidity Meter using Turbidity Sensor & Arduino*. How to Electronics. Retrieved June 12, 2024, from https://how2electronics.com/diy-turbidity-meter-using-turbidity-sensor-arduino/

[22] RF Wireless World. *Ultrasonic Sensor Calculator | Distance, time calculation*. Retrieved June 12, 2024, from https://www.rfwireless-world.com/calculators/Ultrasonic-sensor-calculator-for-time-distance-calculation.html