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Flood early warning monitoring system and water depth limit in the Curug Dhuwur river tourist area, Bumisari Village

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ABSTRACT

Waterfall tourist attractions are generally located in mountainous areas or at the foothills of mountains, far from residential settlements. Due to their geographical location, tourism managers face difficulties in monitoring environmental conditions and tourist activities. At Curug Dhuwur Waterfall, unpredictable weather changes can cause sudden fluctuations in water quality and water levels, posing safety risks to tourists due to unexpected changes in water flow. Previous studies have mainly focused on monitoring water levels and water quality without integrating tourist activity monitoring into a single system. Therefore, this study aims to design and implement an Internet of Things (IoT)-based early warning and tourist swimming activity monitoring system capable of monitoring water levels and tourist activities in real time to improve visitor safety and support disaster mitigation efforts. The system was developed using the prototyping method and consists of a NodeMCU ESP8266, an ultrasonic sensor, a turbidity sensor, and a laser receiver integrated with a website and Telegram platform. System functionality was evaluated using black-box testing, while user satisfaction was assessed using the System Usability Scale (SUS). The results indicate that the proposed IoT-based system can assist tourism managers in monitoring water conditions and visitor activities more effectively, with an ultrasonic sensor measurement accuracy of 98.33%. The SUS evaluation produced a score within Grade Scale D and the High Acceptability Range, indicating that the system is acceptable for use by tourism managers. In addition, the system successfully delivered monitoring information and warning notifications through both the website and Telegram platform according to the detected conditions. The implementation of the IoT-based monitoring system enables tourism managers to respond more quickly to potential flood hazards and unsafe swimming activities, thereby improving visitor safety and supporting disaster mitigation efforts.

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Introduction

Indonesia has abundant natural resource potential, especially in the tourism sector to increase economic growth in a region. In an effort to improve the economy of the ecotourism concept, tourism in

Purbalingga Regency through the High Waterfall is one of them (Fitriyani, 2023). Curug Dhuwur is in great demand by tourists, both local and out-of-region tourists, but still does not pay attention to safety for tourists (Parida, 2021). Through the local government, POKDARWIS as a tourism manager is allowed to manage the High Waterfall tourism (Fujiyama & Wipranata, 2020). The Tinggi Waterfall located at the foot of Mount Slamet makes it difficult to estimate water conditions due to erratic rainfall coupled with the relatively long distance from the location of the waterfall to community settlements (Haidi et al., 2023). On April 8, 2023, a student in Purwokerto reportedly died from swimming at a point where he was not allowed to swim. The relatively remote location of the waterfall makes it difficult for fellow victims to seek help (Vandi, 2024). Technological developments such as the internet of things are currently widely applied in various sectors, especially tourism (Soelistianto et al., 2024). The Internet of Things can be an option to overcome the problems that occur in the Tinggi waterfall tourism so that management can monitor tourists and water (Ramadhan et al., 2019). Utilizing the proximity turbidity sensor, the water and laser receivers connected to the ESP 8266 MCU Node, can send messages to telegrams and websites (Udin et al., 2021). By leveraging the Internet of Things, management can identify travelers from relatively long distances (Damiri et al., 2022). If something unexpected happens, management can take immediate action (Ramadhan, 2024).

Several international studies explain that IoT-based flood monitoring systems improve real-time monitoring and disaster mitigation through cloud communication and sensor integration (Diriyana et al., 2019; Rizal et al., 2024). Previous studies have also shown that ESP8266 combined with ultrasonic sensors can provide stable and accurate monitoring of water levels in environmental applications (Salim et al., 2022; Kharisma & Puspitaningrum, 2025). Real-time notification systems using Telegram and cloud services are widely implemented in intelligent monitoring systems as they allow for the rapid deployment of alerts to tourism managers and visitors (Febriani et al., 2025; Lai et al., 2019). Modern IoT-based environmental systems are increasingly integrated with turbidity sensors, edge processing, and cloud analytics to improve water quality analysis and monitoring performance (Islam et al., 2024; Hasib et al., 2026).

Research Methods

The stages of research that will be carried out in this study can be seen in Figure 1. The picture is an explanation of the stages to be carried out.

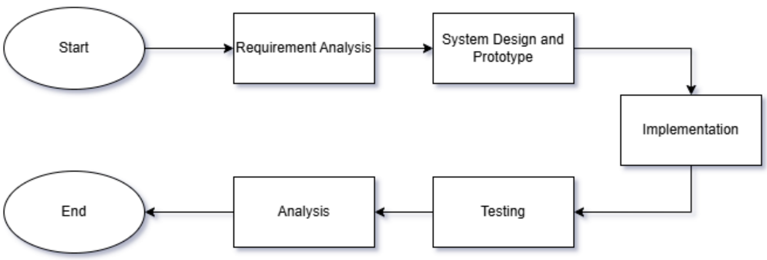

Figure 1. Explanation of the stages

The researcher selected the prototyping method for system development because it enables an iterative design process in which the system can be evaluated and refined before final implementation. The prototyping approach is well suited for Internet of Things (IoT) development, as it involves the integration of both hardware and software components. Black-box testing was employed to evaluate the functionality of the hardware and software components of the proposed system. To assess user satisfaction and usability, the System Usability Scale (SUS) method was used in conjunction with a snowball sampling technique. Initial respondents were selected from the tourism management staff (POKDARWIS), who subsequently recommended tourists visiting the tourist area to participate in the study. A total of 35 respondents were involved, consisting of 5 tourism managers and 30 tourists.

2.1 Requirements Analysis

The first stage is to analyze what is needed in the development of this research. This need includes everything that needs to exist before the implementation stage. The needs needed include:

A. Software
   a. Arduino IDE
   b. Visual Studio Code
   c. Telegram
   d. Php myadmin

B. Hardware
   a. Node MCU ESP 8266
   b. Male & Female Cable Jumpers
   c. ESP 8266 flat board base
   d. Sensor ultrasonik
   e. Laser receiver
   f. Laser
   g. Sensor Kekeruhan
   h. Cable USB
   i. 18650 Battery
   j. Holder baterai
   k. MIFI Devices
   l. Lower dc to dc

2.2 Sensor Calibration

Sensor calibration was performed to determine the reading values of the ultrasonic sensor and turbidity sensor using several reference samples. The ultrasonic sensor was calibrated by comparing its measurements with actual water level distances measured using a ruler. Meanwhile, the turbidity sensor was calibrated using several water samples with different levels of clarity. The threshold values for the ultrasonic sensor were determined based on field observations conducted in the tourist area to classify water-level conditions. The threshold values for the turbidity sensor were established by testing several water samples and analyzing the corresponding sensor readings to define water clarity categories. A water level status of *Rise* was assigned to distances between 0–50 cm, indicating that the water surface was approaching the sensor. A *Normal* status was assigned to distances between 100–150 cm, while a *Surut* status was assigned to distances greater than 150 cm. For the turbidity sensor, values below 50 were categorized as *Clean*, values between 50 and 90 as *Normal*, and values above 90 as *Kotor*, based on the results of water-sample testing conducted in this study.

2.3 System Design and Prototype

System design is a stage that focuses on how the system will be created. This design includes creating a schematic of how the system will run later(Nistrina & Lestari, 2024). In this case, it means how this system can work and send alert notification data to the chatbot chatbot Telegram and Websete when the sensor has read a value that exceeds the specified limit. The design scheme of the system to be created is illustrated in Figure 2:

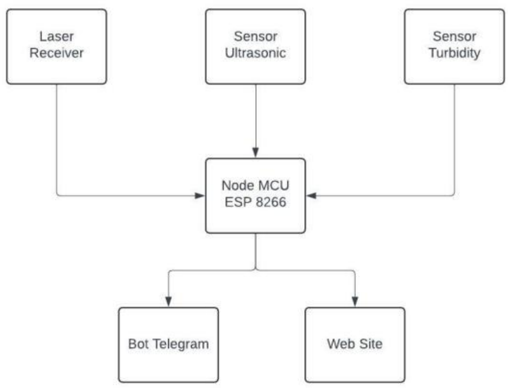

Figure 2. Block Diagram

In the block 2 diagram there are 3 sensors as inputs and 2 outputs. The laser receiver will receive the Light from the laser fired. The ultrasonic sensor will measure the water level, in this case the ultrasonic sensor will accept whether there is a change in water level or not. The turbidity sensor will capture the results of the water clarity. All data will be processed by ESP 8266 MCU Node.

In Output there are 2, namely telegram bots and websites. Telegram bots will respond when there is a significant data change, especially when the laser receiver is not receiving light. The website is used to monitor real-time data received by the ESP 8266 MCU Node, so that POKDARWIS as a tourism manager can monitor data changes that occur. The researcher chose the telegram platform because telegram is an application that has an excellent API than other platforms, making it easily accessible to developers. Telegram's bot API allows interaction with the ESP 8266 MCU Node flexibly. The process of creating a telegram bot is fairly easy compared to other applications. Telegram makes it easy for its users to access a huge number of bots and channels, so that in the study every member of POKDARWIS can access them on any device.

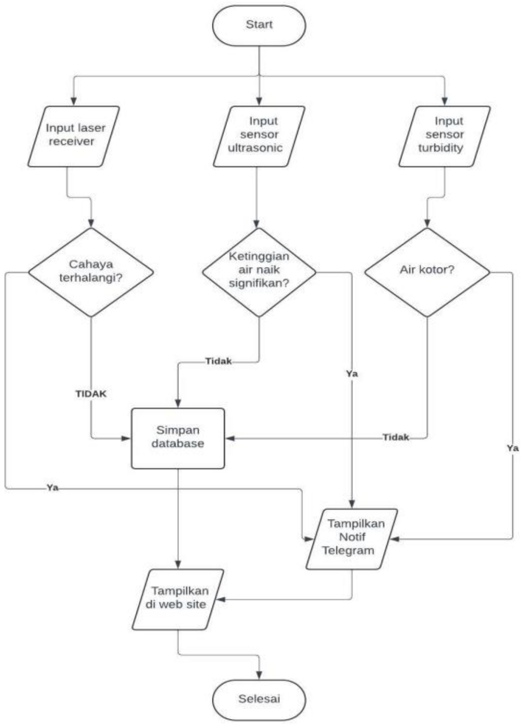

Figure 3. System flowchart

In the flowchart system, there are 3 inputs, namely from the laser receiver, ultrasonic sensor and turbidity sensor. Third, the sensor readings will meet 2 conditions, if the conditions are met, the telegram bot will display a notification while it does not, then all data readings will be stored in the databse. Thus, if the conditions are met, the data will also be stored in the databse as real-time data monitoring. The website will display real-time data readings that have been stored in databse with the aim that POKDARWIS as administrators can monitor sensor readings in real-time. Data can be used if management needs it at any time.

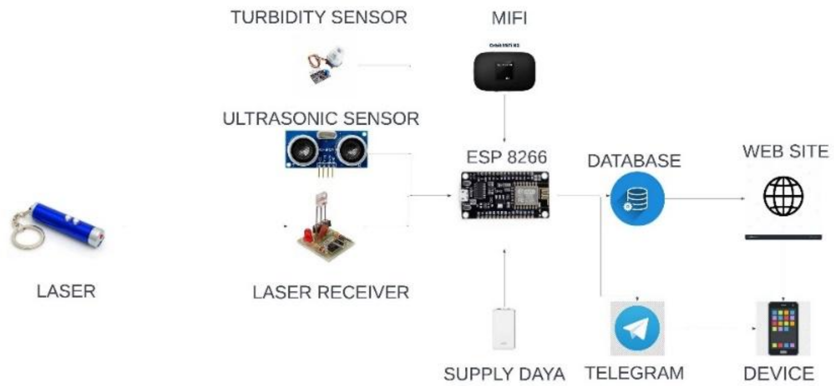

Figure 4. System planning scheme

Based on figure 4. The ESP 8266 MCU node requires power to power the sensor. In the study, the researcher will use 6.18650 batteries. MIFI devices require a voltage of 5v. The 18650 battery in full condition has a voltage of 4.2v and a capacity of 2000mAH. In the study, 6 batteries will be divided into 2 parts, the first part for the sensor module while the second part for the MIFI module. The MCU node requires a voltage of 5 – 10v, but the input voltage is 12.6v so in the system it takes a step down dc to dc to lower the voltage from 12.6v to 10v to 5v. The same is also the case with MIFI modules that require a voltage of 5v so they require a step down from DC to DC.

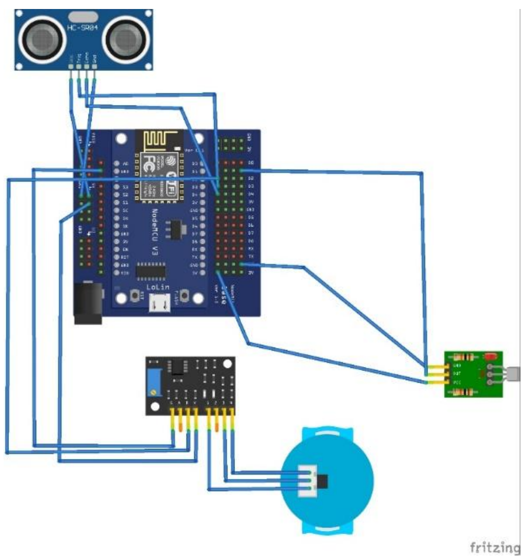

Figure 5. Tool design scheme

In this study, a system will be designed as shown in Figure 5. where the laser receiver will receive the laser beam from the laser fired. From the laser beam it will make it like a straight line, in this case it is a limit where tourists are not encouraged to swim beyond the limits of danger that have been created. In Figure 3.3.1.3 the ultrasonic sensor will measure the water level, the ultrasonic sensor requires a voltage of 5 while the turbid sensor interface module also requires a voltage of 5, but the MCU node ESP 8266 has a 5 vol pin of only 2 pins, so in the study it requires a base plate board of the ESP 8266 MCU Node as a power input source.2.3 Implementation

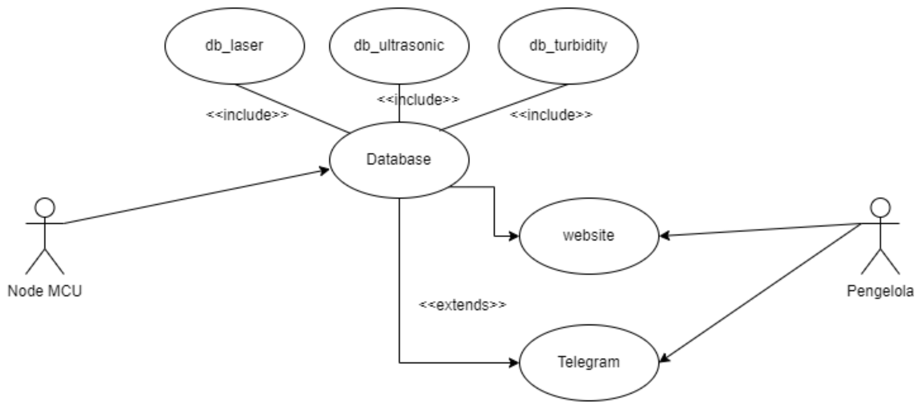

Figure 6. Use Softwere Casing

Management can access real-time laser monitoring data, water rise data, and water clarity through the website. Management can send warning messages through telegram bots.

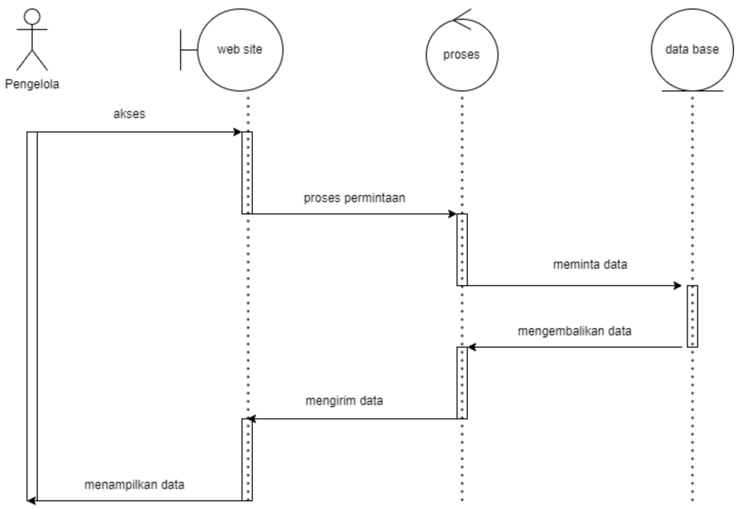

Figure 7. Sequence diagram

In figure 7. is a sequence diagram in which managers will access the website software to view the data. The data to be displayed will be requested first through the database.

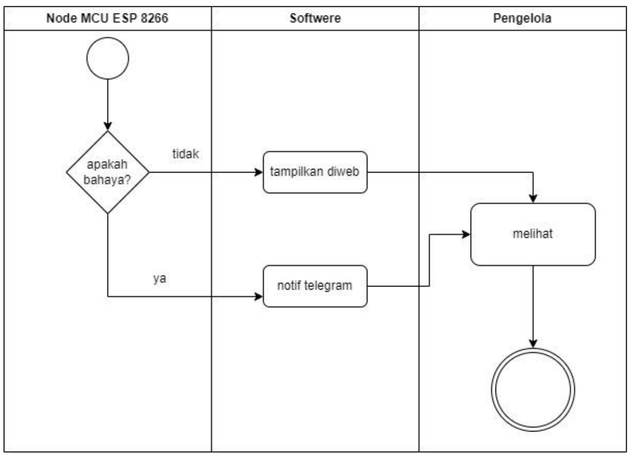

Figure 8. Activity diagram

In figure 8. is a sequence diagram, the MCU node will provide a branching of whether or not the data obtained from the sensor reading results exceeds the predetermined limit. Otherwise, the data will be stored in databse. The results of this data reading are the results of reading data in real time. If the branched condition is correct, it will display a notification on Telegram. Managers can view data from websites (real time) and notifications.

Results and Discussion

In Figure 9 the laser design uses 2 18650 batteries as a power source to power the laser. The total voltage generated from the 2 18650 batteries is 7.4 Volts. With a total mAH of 13600mAH so that it can turn on the laser for 194.29 hours if turned on continuously. Calculation using the formula:

(Battery Capacity (mAH))/(Current Consumption (mA))

The laser can work optimally at a voltage of 5 Volts, but the input from the battery is 7.4 Volts, so a DC step down is required to lower the voltage from 7.4 Volts to 5 Volts to avoid overheating the laser device that can cause damage to the laser.

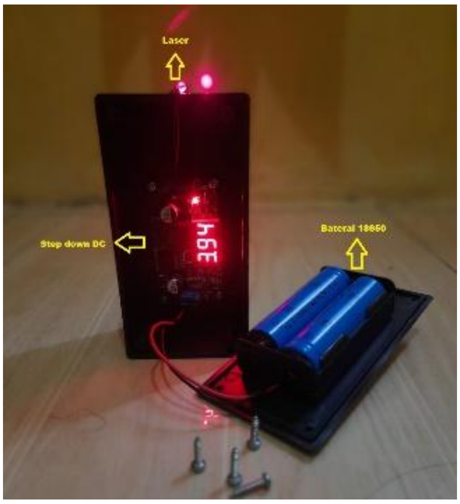

Figure 9. Laser

In Figure 9. The power source used to power the Node MCU ESP8266 uses an external power source of 18650 3 batteries with a voltage of 11.1 Volts and 20400mAH. The ESP 8266 MCU node consumes 200mA of power, with the following calculation formula:

(Battery Capacity (mAH))/(Current Consumption (mA))= hours

The lack of pins available on the ESP 8266 MCU Node makes it difficult to assemble the tool, requiring a base plate board that allows all sensor pins to be connected. The ESP 8266 MCU node works at a voltage of 5 – 10 Volts, if at a voltage of 5 Volts the senor works less than optimally, the voltage can be increased through a potentiometer at the step down DC.

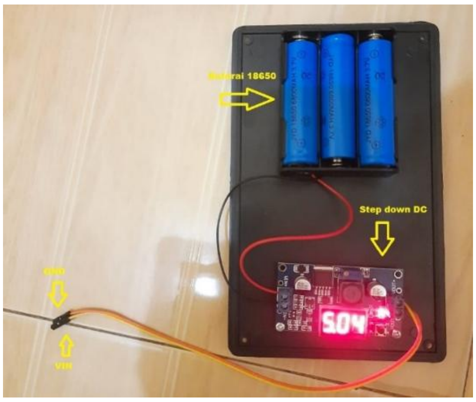

Figure 10. MCU NODE ESP 8266 resources

The laser receiver sensor lights up at the bottom of the *box* so that the light reception can be precisely and easily adjusted up and down as shown in Figure 4.3. The VCC pin on the laser receiver is connected to the 5V pin on the *base plate board*, the laser receiver OUT pin is connected to the D1 pin on the base plate board and the GND laser receiver pin is connected to *the GND pin base plate board*. On the laser receiver there can be a small red light, if the light is on, the installation of the laser receiver on the MCU ESP 8266 Node is correct.

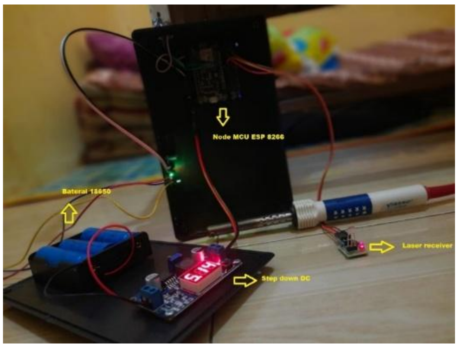

Figure 11. Laser receiver

The installation of the ultrasonic sensor is on top of the box with a distance of 40 cm so that if the water level is just below the laser receiver, the system keeps reading the distance with a normal state. In figure 4.4 the GND ultrasonic sensor pin is connected to *the GND base plate board*, the ultrasonic sensor VCC pin is connected to the 5V *base plate board pin* , the ultrasonic sensor Triger pin is connected to the *D5 base plate board* pin and the ultrasonic sensor Echo pin is connected to *the D6 base plate board* pin .

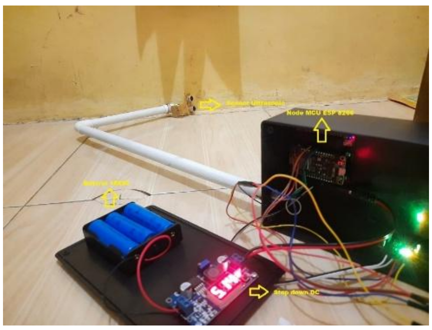

Figure 12. Ultrasonic sensor

The turbidity sensor will take a sample of water, therefore so the turbidity sensor is installed outside the *box* and immersed in the water stream. However, the turbidity sensor module is in the *box* to avoid hardware damage. In Figure 13. turbidity sensor there are 3 wires in red, dark blue and yellow. The red wire is connected to the sensor module of pin number 1, the blue wire is connected to pin number 2 of the module and the yellow wire is connected to pin number 3 of the module. On the module pin G is connected to *the base plate board* of the GND pin, the module A pin is connected to pin A0 on *the base plate board* and the V pin of the module is connected to the 5V pin *of the base plate board*.

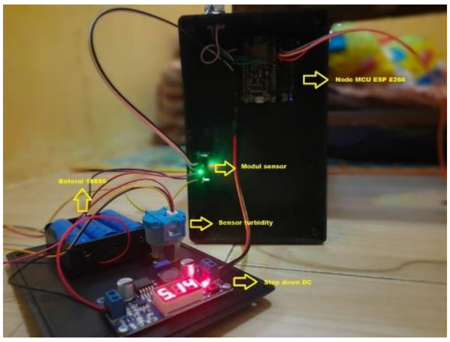

Figure 13. Sensor turbidity

In Figure 14. The design of the system and the laser is installed using a tripod to adjust the height and short easily, this is done so that the laser beam can be received precisely by the laser receiver. Turbidity sensors are installed under the system as they are submerged in river water.

Figure 14. Sensor Placement

Figure 15 The website display is designed to be responsive so that the font and container sizes can be automatically adjusted to the screen size used by the user. There are 3 containers, namely laser containers, water containers and water clarity containers. The laser receptacle will display the status of the laser receiver, just like the water rise receptacle displays the water rise data from the ultrasonic sensor. The clarity container takes data from the cloudy database and then displays it on the website, on the website it also displays a status that if the cloudiness value is less than 50 then it will display a clean state, if the cloudiness value is more than 50 and less than 90 then the status is normal. Meanwhile, if the value is more than 90, the water status becomes dirty. All the data displayed on the website is basically taken from the respective tables available in the database.

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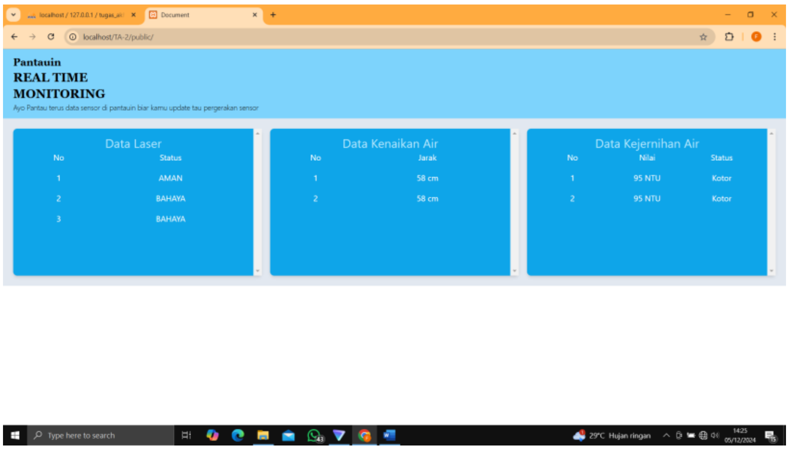

Figure 15. Website display

2.4 Testing

The testing stage is the stage to evaluate the overall performance of the system whether the system is functioning as expected or not.

Table 1. Testing the laser receiver

No	Laser distance from laser receiver (cm)	Status
1	100	Secure
2	1000	Secure
3	5000	Secure
4	10000	Secure
5	15000	Secure

Laser Receiver testing is performed by firing a laser beam directly into the receiver laser. Based on the results of the laser receiver test in table 1 above, it shows that the laser receiver is able to receive laser light up to a distance of 15 meters. The data received by the ESP 8266 MCU Node will be sent to the database and telegram. The Safe status is if the laser receiver is HIGH while the Danger status is if the laser receiver *is LOW.* The Telegram bot will create a notification if the laser recipient has *a LOW* value, this can be seen directly through *the telegram* bot.

The results of this study are consistent with the research conducted by Handayani, Widiantoko, and Saputra [15], which utilized laser sensors and laser receivers to detect bird pests in rice field areas. In their study, the laser receiver was used as a parameter to activate a servo motor as a bird-repellent mechanism. In contrast, the present study employs the laser receiver as a sensor for monitoring tourist activities by utilizing interruptions in the laser beam as an indicator of object presence. This difference demonstrates the high flexibility of laser receiver technology and its applicability to various monitoring system requirements. Furthermore, the testing results, which showed a detection range of up to 15 meters, indicate that the laser receiver has strong potential for use in tourist safety monitoring systems within the Curug Dhuwur tourist area.

Table 2. Ultrasonic sensor testing

No	Distance of the ultrasonic sensor to the water	Status
1	10	Rise
2	50	Rise
3	100	Normal
4	150	Normal
5	160	Surut

Based on the table 2 of the tests above, the ultrasonic sensor can read the status of the water rising when the water is approached from a distance of 0 to 50 cm. At a distance of 100 to 150cm, the ultrasonic sensor reads the water level with the status of Normal. At a height of 160cm the water status will change to recede. The author conducted a test facing the ultrasonic sensor by bringing the dipper water closer to the ultrasonic sensor whose height has been measured by the author using a rod.

The findings of this study are consistent with the research conducted by Misnawati, Nas, Fadlia, and Marsing [14], which also utilized an ultrasonic sensor for monitoring water levels in a dam environment. In their study, the ultrasonic sensor was integrated with an ESP32 microcontroller and a website interface to assist dam operators in monitoring water level changes. Similarly, the present study employs an ultrasonic sensor as the primary component for water level monitoring. However, unlike the previous study, this research integrates water level monitoring with tourist activity monitoring and an early warning notification system through Telegram and a web-based platform. The ultrasonic sensor achieved an accuracy of 98.33%, indicating that it is sufficiently reliable for real-time water level monitoring in the Curug Dhuwur tourist area.

Table 2. Sensor turbidity test

No	Air	Value	Remarks
1	Air Faucet	47	Clean
2	River Water	58	Normal
3	Sand Water	93	Kotor

Based on the 3 test tables, the author used 3 different water samples to test the turbidity sensor, based on the table above, the tap water tested by the turbidity sensor had an average value of 47 which means the water was clean, while the river water produced an average value of 58 which means the water was in a normal state. In water that has been mixed with sand, until the water is cloudy brown, the value is 93 so that the water is dirty.

The findings of this study are consistent with the research conducted by Susilo, Maulindar, and Yuliana [12], which emphasized the importance of water quality monitoring in supporting catfish farming activities. In their study, water quality monitoring was performed using an ESP32 microcontroller and IoT technology to assist fish farmers in maintaining suitable water conditions. Similarly, the present study utilizes IoT-based monitoring to observe water quality conditions through a turbidity sensor. However, unlike the previous study, which focused on aquaculture environments, this research applies water quality monitoring in a waterfall tourism area to support visitor safety and environmental monitoring. The ability of the turbidity sensor to classify water conditions into clean, normal, and dirty categories demonstrates its potential as an effective tool for real-time water quality monitoring in the Curug Dhuwur tourist area.

Table 4. Black box testing

No	Soft	No menu	Infant	Remarks
1	Website	1	Laser container	Works
		2	Container Turbidity	Works
		3	Ultrasonic Containers	Works
2	Telegram	1	/laser	Works
		2	/Ketingiian	Works
		3	/Clarity	Works

Based on the test results of table 4. *The black box* above the feature on the website that displays real-time data on each sensor can work according to the author's expectations. The ESP 8266 MCU node can send data to *the database* and the website can display the data in *the database*. Not only sending data to *the database*, but the ESP 8266 MCU Node also successfully connected to *the telegram* bot. *Telegram bots* are capable of responding to the menu options that have been provided, including the /laser, /height and /clarity menus. *The* telegram bot managed to display the status of the censorship reading results as expected by the author.

Table 3. Ultrasonic sensor error percentage

No	Time	References	Sensor	Status	Differences	Accuracy	Error Percentage
1	1 minute	15 cm	16 cm	Rise	1 cm	93.33%	6.67%
2	1 minute	52 cm	52 cm	Normal	0 cm	100%	0%
3	1 Minute	65 cm	65 cm	Normal	0 cm	100%	0%
4	1 minute	107 cm	107 cm	Normal	0 cm	100%	0%
	1,67%						

To find out the error of the ultrasonic sensor data reading results, you can use the following formula:

$$\text{Error Percentage} = \frac{Nilai\ sensor - nilai\ referensi}{nilai\ referensi} \times 100\%$$

$$\text{Accuracy} = 100\% - Persentase\ error$$

$$\text{Average error} = \frac{Jumlah\ semua\ persentase\ eror}{Jumlah\ data}$$

Based on table 5, the ultrasonic sensor in reading the water level achieves an error of up to 1.67%, so the accuracy rate of the ultrasonic sensor in reading the water level reaches 98.33%. With an accuracy rate of 98.33%, the system can run well. The ultrasonic sensor achieved an accuracy level of 98.33%, which was influenced by the stable installation of the sensor, its perpendicular position relative to the water surface, and testing conducted within the sensor's specified measurement range. A stable 5V power supply provided by the 18650 batteries and a DC step-down converter enabled the sensor to operate optimally and in accordance with its technical specifications, allowing distance measurements to be performed consistently. However, environmental factors such as water waves, water splashes, temperature variations, and sensor placement may introduce measurement errors and affect the accuracy of the readings.

Table 4. Voltage Error Percentage MCU ESP NODE 8266

No	Tegangan	Sensor	References	Results	Error	Percentage
1	5,01V	Ultrasonic	81 cm	81	0	0%
		Turbidity	54	55	0	0%
		Laser receiver	HEIGHT	HEIGHT	0	0%
2	4,03V	Ultrasonic	81	81	0	0%
		Turbidity	54	40	14	25,9%
		Laser receiver	HEIGHT	HEIGHT	0	0%
3	3,05V	Ultrasonic	81	Data Not		100%
		Turbidity	54	Delivered		
		Laser receiver	HEIGHT			
4	2.56V	Ultrasonic	81	Data Not		100%
		Turbidity	54	Delivered		
		Laser receiver	HEIGHT			

To find out the percentage of sensor reading errors based on *the input voltage* assigned to the ESP 8266 MCU Node, you can use the following formula:

$$Persentase\ eror = \frac{eror}{referensi} \times 100$$

Meanwhile, to calculate the value, you can use the following formula:

$$eror = Referensi - Hasil$$

Based on table 6, it can be seen that the ESP 8266 MCU Node can work optimally without producing errors at the 5V voltage, i.e. the voltage that should be input to the ESP 8266 MCU Node, while at 4.03 V the test results in an error percentage at the turbidity sensor which is 25.9%. The ESP 8266 MCU node cannot operate at voltages below 4V, the table shows that the data is not sent to the website.

The System Usability Scale test involved 35 respondents consisting of 30 tourists and 5 tour managers. The questions consist of 10 questions and each question has 5 answer options from Strongly Agree (ST) to Strongly Disagree (STS). The calculation of the conversion of the answer in the SUS method on odd questions uses the following formula:

$$pertanyaan\ ganjil\ = jawaban - 1$$

Meanwhile, even questions can use the following formula:

$$Pertanyaan\ genap\ = 5 - jawaban$$

Table 5. Table *System Usability Scale*

No	Name	Role	SUS Results										Quantity	Shoes
			Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q 10		
1	Nice Setiawan	Tourists	4	3	3	2	4	4	3	3	3	3	32	80
2	Zyulfikar Faryd Prianto	Manager	4	4	3	3	4	2	3	4	4	3	34	85
3	Arya Marcello Salas	Tourists	3	3	3	2	3	2	3	3	3	1	26	65
4	Firm p	Manager	3	3	3	1	3	3	3	3	2	1	25	62,5
5	Wise Man	Tourists	3	2	4	1	4	0	3	0	3	2	22	55
	...	...												...
35	A Son of Man	Tourists	3	2	3	2	4	3	3	3	3	0	26	65
			Total Score										2.260	
			Average score										64,57	

Based on table 7 of the results *of the SUS calculation* that has been carried out from the results of the questionnaire using *the System Usability Scale method*, the total *score* is 2,260 from 35 respondents consisting of 30 tourists and 5 administrators. The average score of the total respondents reached 64.57, this figure was obtained using the following formula:

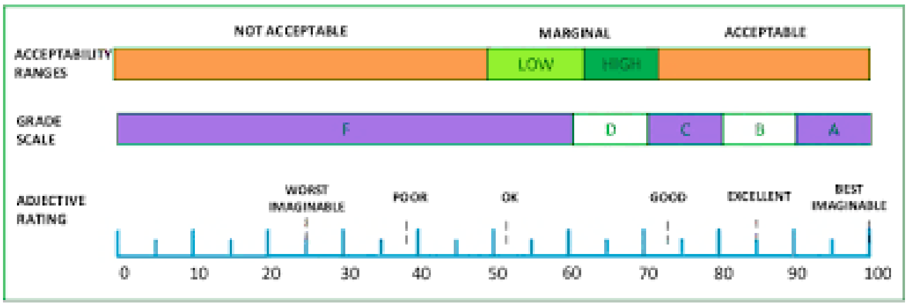

Image 1. Average SUS score categories

Based on Figure 4.8, the system that has been designed by the author is at *Grade Scale* D and *Acceptability Range HIGH.* The results show that the system is still acceptable even though it is below the limit of the good category. The system that has been built by the author meets the basic standards that can be accepted by the user, so the system is considered *acceptable*. The SUS score obtained was influenced by several factors, including the relatively simple user interface, respondents' unfamiliarity with the Telegram Bot, and the lack of usage instructions for certain features. In addition, most respondents were tourists who had little or no prior knowledge of IoT-based monitoring systems, requiring additional time to understand the system's functions and how to operate it. To improve usability, the system requires a more modern and interactive user interface that is easier for novice users to understand. Furthermore, the use of a mobile application as a replacement for the Telegram Bot, along with more comprehensive user guides and informative explanations regarding IoT technology, could enhance the overall user experience. These improvements are expected to increase user satisfaction and contribute to a higher SUS score in future evaluations.

Although the developed system successfully performs real-time monitoring of water levels, water quality, and tourist activities, several limitations should be considered. First, the system is powered by 18650 batteries, which prevents continuous operation without interruption. This power limitation requires the batteries to be recharged regularly to maintain system functionality. Second, the geographical location of the tourist area and weather conditions can affect internet connectivity, resulting in slower data transmission between the monitoring devices, website, and Telegram platform.

In addition, environmental factors such as fallen branches, debris, and other objects commonly found around the waterfall area can easily shift the position of the laser and laser receiver. This may reduce the accuracy of the system in detecting tourist activities and lead to inaccurate data readings. Furthermore, the field testing conducted in this study was limited in terms of location, duration, and the number of testing scenarios. Therefore, the results may not fully represent all conditions that could occur in the Curug Dhuwur tourist area. Future studies should conduct longer-term testing under various weather and environmental conditions to obtain more comprehensive results and further evaluate the reliability of the system.

Despite these limitations, the developed system has demonstrated considerable potential in supporting real-time monitoring of water levels, water clarity, and tourist activities. The system can assist tourism managers in improving visitor safety, enhancing response times to potential hazards, and supporting disaster mitigation efforts in waterfall tourism areas.

Conclusion

The implementation and testing results demonstrate that the developed system enables POKDARWIS, as the manager of Tinggi Waterfall tourism, to monitor water conditions, including water level and water clarity, through a website and Telegram bot. The system also supports tourist monitoring using a laser receiver with a detection range of up to 15 meters and provides automatic warning notifications via Telegram to improve visitor safety during emergency situations. Performance evaluation showed that the ultrasonic sensor achieved an accuracy of 98.33% in measuring water levels, indicating reliable environmental monitoring. Usability testing using the System Usability Scale (SUS) produced an average score of 64.57, corresponding to Grade Scale D and the High Acceptability Range, suggesting that the system is generally acceptable to users despite requiring further improvements in usability. Several limitations were identified during the study. The system depends on rechargeable 18650 batteries, which require periodic charging for continuous operation. In addition, unstable internet connectivity in the waterfall area affects data transmission and communication between hardware and software components. Future research should focus on improving system performance, reliability, and user experience. The integration of Artificial Intelligence (AI) techniques may enhance early detection and prediction of potential flood hazards. The adoption of micro-hydropower generation as an alternative energy source could reduce dependence on battery recharging, while satellite-based internet services, such as Starlink, may improve communication reliability in remote areas. Furthermore, replacing the Telegram Bot with a dedicated mobile application could provide a more intuitive interface and further enhance the effectiveness and usability of the monitoring system.

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