Monitoring River Sediment by Optimizing Arduino Capabilities Controlled by the PID Algorithm

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Abstract: - Sediment causes serious water problems, including flooding, water pollution, and other issues related to water sediment. The data found that 82% of the 550 rivers in Indonesia were polluted and in critical condition. Hence, river maintenance is essential, especially for monitoring the existence of river sediment.
This research makes a device to monitor sediment in the river and measure its volume. The device consists of a small boat in which an Arduino Mega 2560 RS microcontroller was an Arduino Mega 2560 RS microcontroller which will control sensors, motors, and a rotary encoder in monitoring and measuring sediment. This paper explained how Arduino could move the boat looking for sediment, detect sediment with infrared sensors, raise and lower the sensor by adjusting the motor in front and behind the boat and finally calculate the volume of sediment. The electronic circuits, block diagrams, and programs used are described in detail in this paper and discuss sensor accuracy and accuracy of measurement results.
The result is the device can detect the sediment, measure the height of the sediment, trace the sediment to measure its length, and then rotate to measure the width of the sediment. All movements are carried out by utilizing the capabilities of Arduino. The PID algorithm can precisely determine the initial position of the sensors. It can detect sediment accurately. The measurement results show that the device can work well with a relatively small error.

Key-Words: - Arduino, sediment, electronic circuits, infrared sensor, DC motor, accuracy.

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1 Introduction

The majority of Indonesia's rivers are contaminated. The quantity of silt in the riverbed is one of the factors contributing to river pollution. Floods have many causes, one of which is sediment in rivers. According to the report, 550 of Indonesia's rivers were contaminated and in serious condition in 82% of the cases, [1].

A study of adaptive control for the DC motor using meta-heuristic algorithms explained the simulation results that proposed adaptive control strategies as a viable alternative to regulate the speed of the motor subject to different operation scenarios. The comparative analysis with a robust control approach revealed the advantages of the adaptive strategy based on the meta-heuristic techniques in the velocity regulation of the DC motor, [2].

An Overview of the Next-Generation Underwater Target Detection and Tracking: An Integrated Underwater Architecture provided a comprehensive survey of Unmanned Underwater Vehicles (UUV) and other ray tracing, models. These were essential in target detection and tracking to answer several questions regarding the current necessities of underwater networks. Finally, it provides a solution that allows community research to excel in this area, [3].

Soetjie Poernama Sari, [4], studied detection and interpretation of the target on the ocean floor using a side scan sonar instrument conducted in the waters of East Aceh, Lhokseumawe. The results showed that the value of the reflected signal from the pipe and the unknown object are 1- 2.5 Voltage/Div, silty sand of 0.5 - 1 Voltage/Div, and mud is 0-0.5 Voltage/Div. Using FFT calculation of the amplitude spectrum, the value of the pipe is higher than other objects, and it is about 1412 Volt/dB. The value of amplitude unknown object, mud, and silty sand are 834.0728 Volt/dB, 106.2367 Volt/dB, and 238.9427 Volt/dB.

An article declared the challenge of tracking and estimating the size of a single submerged target in a high-reverberant underwater environment using a single active acoustic transceiver studied in 2019. This problem is common for many applications, ranging from the security and safety needs of tracking submerged vehicles and scuba divers to environmental research and management implications such as monitoring pelagic fauna, [5].

A sensor for continuous monitoring of sedimentation, or erosion, of marine sediments has been developed and tested. The method uses the difference in the electrical conductivity of seawater and sediments (up to a factor of 4). The conductivity change grossly distorts the voltage field generated by a current source close to the interface. The sensor takes the form of a thin rod carrying ring electrodes along its length. The sensor is driven into the sediment and responds to the position of the sediment/seawater interface along the rod, [6].

Assaf and Petriu, [7], used Unscented Kalman Filter (UKF) for tracking ships using Global Positioning System (GPS) data. The present work proposes to exploit information from GPS sensors to track a boat in real time. KF theory examines GPS coordinates and compares current marine vessel itineraries to previously noted ones to solve the ship’s absence and presence problem. The system was constructed in C++ to evaluate tracking performance, and simulation results show that the suggested tracking method is workable and accurate. Research using the KF algorithm aims to track objects in the water, in this case, detecting ships. The tracked object is moving and has very different characteristics from sediment.

The study is about developing a satellite-based monitoring system for the observation of turbidity discharged from multiple rivers and investigates the applicability of the developed monitoring system through a case study on the northern coast of Vietnam. A formula was determined to estimate the surface water turbidity as a function of the redband reflectance of Moderate Resolution Imaging Spectroradiometer (MODIS) images. Long-term trends in turbidity patterns from multiple rivers were compared with in-situ observation data. It was discovered that the Red River and the Ma River showed contrasting characteristics, which reasonably explain recent coastal shoreline changes and sediment sampled along the coast, [8].

University researchers collaborated with the Bangladesh Water Development Board (BWDB) [9] and developed a cloud-based satellite remote sensing tool for monitoring suspended sediment concentrations (SSC) in major Bangladesh rivers. The tool helps overcome BWDB limited resources and ground-based monitoring capacity constraints. The tool maps estimated SSC over satellite images and provide long-term estimated SSC time series at user-designated points, [9].

Sediment problems that have not been resolved optimally need to be handled, so it is necessary to make a device that can automatically detect the volume of sediment in the river, so that river conditions can continually be monitored quickly to anticipate if the sediment size has reached a dangerous situation. Many studies have been conducted to detect objects in the water, but so far, no one has predicted the volume of these objects, mainly sediments.

2 Problem Formulation

This study aims to create a device for detecting the volume of sediment in an actual river. The device is equipped with sensors that will detect objects at the bottom of the river. There are 3 (three) sensors installed below and on the right and left of the device with different functions. The rise and fall of the front sensor are controlled by a DC motor mounted on the prototype. After the sensor detects an object, the information from the sensor is forwarded to the Arduino, where the data is processed to drive another DC motor as the device propulsion, forward or rotating. A rotary encoder is prepared to calculate the number of revolutions produced by the motor and then begins to predict the sediment length, width, and height. The microcontroller used was selected Arduino Mega 2560.

3 Problem Solution

The microcontroller used is Arduino Mega 2560 the controller and is equipped with an infrared sensor to detect objects in the river. Two DC motors are equipped with a rotary encoder, which is needed to regulate the movement of the infrared sensor.

3.1 Block Diagram System and Flowchart

Fig. 1 shows the diagram block system for the research design. This design consists of three parts: input, process, and output. The input section consists of a power supply, an adjustable infrared sensor switch, and a rotary encoder. The processing section contains Arduino Mega 2560. Then the output section consists of LCD, PG 45 motor, BTS7960 driver and PG28 motor, and Servo motor. The design of this block diagram is intended to make it easier to make the device.

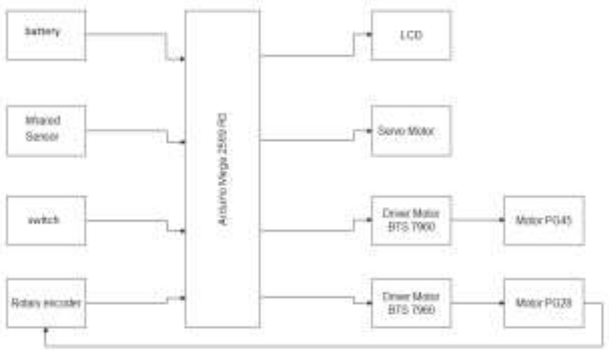

Fig. 1: Block Diagram System

Furthermore, the flowchart of an automatic device for measuring the volume of sediment in the river is shown in Fig.2.

It starts with the rear motor that moves the boat forward, then stops. The front motor starts lowering the infrared sensor until the bottom sensor detects what it considers a riverbed. Next, the rear motor moves the boat forward until the right, and left sensors detect an object considered sediment. The rear motor stops so that the boat stops. The front motor raises the sensor until the side sensor detects no sediment. The rotary encoder records the sediment height. Then the rear motor runs the boat forward until the bottom sensor detects no sediment. The length of the sediment is obtained by calculating the time-detecting sediment. Next, the boat rotates and computes the width of the sediment, just like calculating the length of the sediment.

3.2 Electronics Circuits and Algorithm

In this section, the electronic circuit of the system and the algorithms used are discussed.

We are beginning with Fig. 3 schematics of electronic circuits device.

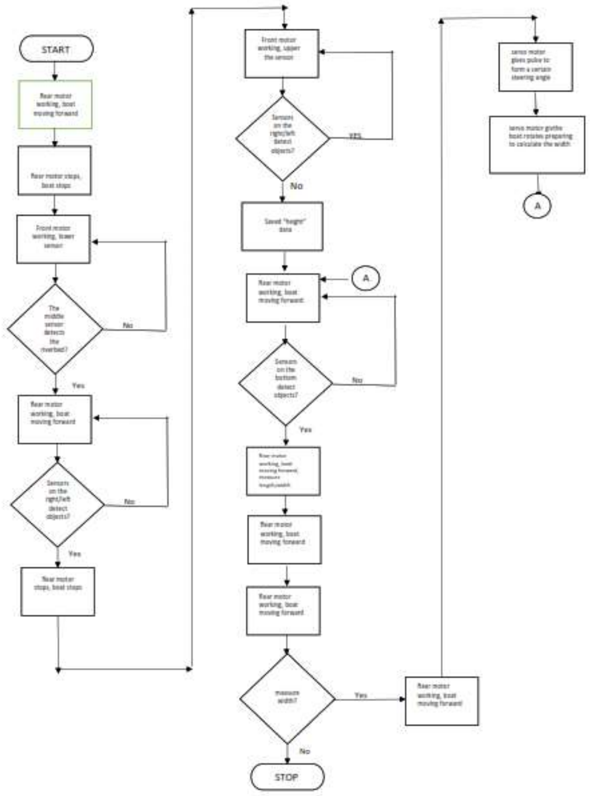

Fig. 2: Flowchart of an automatic device for measuring the volume of sediment

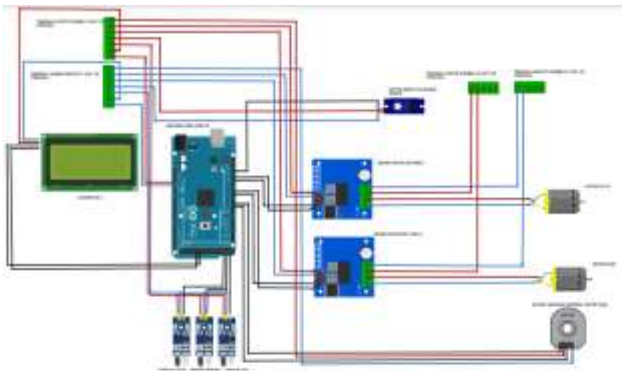

Fig. 3: Electronic Circuit

Fig.3 is an electronic circuit of the device. It used Arduino Mega 2560, two BTS 7960 motor drivers, three Adjustable Infrared Sensor Switch, LCD (Liquid Crystal Display) + I2C, PG45 motor, PG28 motor with internal Rotary Encoder, Hitec HS-5625MG servo motor, DC source 24 Volts, and a 5 Volt DC source. The installed components are categorized into two parts: input and output. The details included in the input category are the Adjustable Infrared Sensor Switch. The details included in the output category are the BTS 7960 motor driver, LCD (Liquid Crystal Display) + I2C, PG45 motor, motor PG28 with internal Rotary Encoder, and Hitec HS-5625MG servo motor. Arduino controls other devices installed with the Arduino IDE software, [10].

The BTS 7960 motor driver is connected to the PG45 motor on pin 10 Arduino for pin L_PWM Motor driver and pin 11 Arduino to pin R_PWM Motor driver. Motor driver BTS 7960 is connected to the PG28 motor on pin 6 Arduino for pin L_PWM motor driver and pin 7 Arduino for motor driver R_PWM pin. Each output pin of the Adjustable Infrared Sensor Switch is attached to a different pin (pin 23 for the left sensor, pin 25 for the centre sensor, and pin 27 for the right sensor). LCD (Liquid Crystal Display) + I2C is attached to pin 42 for the SDA LCD pin and 44 for the LCD SCL pin. The Hitec HS-5625MG Servo Motor is connected to pin 13 of the Arduino for its data pin. Internal Rotary Encoder connected to pin 2 for channel A and pin 3 for channel B. A DC voltage source terminal comes from the battery, and the DC voltage source supplies the electronic components used in this tool.

3.3 Arduino Process

Arduino Mega 2560 will process the input data by a command in the program, then execute it, and the output on the Arduino shows the results. The BTS 7960 motor driver is a direct current (DC) motor controller in this electronic circuit layout. The motor driver controls the output generated from the parallel port I/O computer (Arduino). The signal from the Arduino output is in the form of small signals, so it can not drive the system in the form of a direct current motor. The transistor in the driver circuit is used as a signal amplifier and switching, as well as a DC motor drive relay. The DC motor driver, apart from being an amplifier and switching, is also used to control a DC motor in a reversal system. So, this DC motor driver can adjust the direction of rotation of the motor forward and reverse.

Adjustable Infrared Sensor Switch uses infrared light as a medium for data communication between the receiver and the transmitter. The system will work if the infrared ray emitted is blocked by an object which causes the infrared beam not to be detected by the receiver. For data transmission that uses air as an intermediary medium, it usually uses a carrier frequency of around 30 kHz to 40 kHz. Infra-red emitted through the air is most effective when using a carrier signal with a frequency above. The signal emitted by the sender is received by the infrared receiver and then decoded as a binary data packet. The modulation process is carried out by changing the conditions of logic 0 and 1 into conditions of the presence and absence of infrared carrier signals ranging from 30 kHz to 40 kHz. LCD (Liquid Crystal Display) + I2C as a display of data, whether characters, letters, or graphics. LCD (Liquid Crystal Display) is one of the electronic displays made with CMOS logic technology that works by not producing light but reflecting the light around it to the front-lit or transmitting light from the back-lit. This LCD has I2C installed, which can simplify the cable connection.

Planetary Gear Motor (PG) 45 is a type of motor that can withstand high engine loads. This motor is equipped with a gearbox with varying ratios. The Planetary Gear (PG) 45 motor has a maximum speed of 468.7 rpm. With rounding, the top speed on the output shaft is 500 rpm, with a torque of 25 kg-cm. This motor can be applied as a tool actuator with a supply voltage of 24 V DC. The PG45 motor is the primary driver of the sedimentation measuring device, where in its conditioning, the motor can adjust its speed by adjusting its PWM.

A Servo motor is a DC motor used to control the position with an angle reference. The servo motor is controlled by providing a pulse width modulation (PWM) signal via a control cable. The pulse width of the given control signal will determine the angular position of rotation of the servo motor shaft. The servo motor used in the sedimentation gauge is a Hitec HS-5625MG type with a torque of 7.9 - 9.4 kg/cm and a working voltage of 4.8 V-6 V DC. This motor is used as a boat rudder controller by adjusting the angular position of the propulsion boat.

PG28 motor + internal Rotary Encoder, almost the same as PG45 motor. The PG28 has the same way of working; the difference is that an internal rotary encoder accompanies the PG28 motor.

3.4 Proportional Integral Differential (PID) Algorithm

In general, the PID algorithm is used to evaluate each controller's performance based on rise time, overshoot, steady-state error, and the most common performance criterion, which is the integral of the absolute value of the error, [11].

The PID control function is more to adjust the position. One form of setting that uses PID was experimental data from an SRV-02 DC motor to regulate the shaft position of the motor, [12].

In addition, PID control is also used on the coupled tank control system that has two inputs, which are the inlet flow rate to the tanks, and two outputs, which are the liquid level height inside the tanks. PID controllers are designed and simulated for the best loop pairings of manipulated and controlled variables. In this work, a MIMO system is converted to a multivariable SISO system in the separation process for the coupled tank. In the consideration of
The fuzzy adaptive PID controller is introduced nonlinearity to obtain an excellent control performance, [13].

In this research, the PID algorithm controls the motor in lowering the infrared sensor so that it can be done automatically and immediately stops at a predetermined position. The Kp, Ki, and Kd search results were investigated using trial and error under two conditions. The state when the sensor detects an object at the bottom, but the sensor is not submerged in water, and when the sensor is underwater. Both conditions can be shown in Fig. 4 and Fig. 5.

Fig. 4: The sensor detects the floor base
(not in the water)

Fig. 4 searches for Kp, Ki, and Kd values where the sensor detects objects not in the water. The centre sensor light is on, indicating the sensor has seen an object at the bottom of the floor.

Fig. 5: The sensor detects the water base

Fig. 5 searches for Kp, Ki, and Kd values where the sensor detects objects in the water. The centre sensor light is on, indicating the sensor has detected an object at the bottom of the water.

PID parameter tuning using the Ziegler Nichols closed loop method is based on the two experimental constants, Ku and Tu. The research was carried out and obtained the value of Ku = 3.55 and Tu = 2.4 when the motor is out of the water. Furthermore, the importance of K_p, K_i, and K_d can be obtained based on Table. 1, [14], [15], [16], [17].

By entering each of the K_u and T_u values, we get a value K_p, K_i, and K_d, as shown in Table 2.

Table 1. Ziegler Nichols equation closed loop

Control Type	K_p	K_i	K_d
P	0.5 K_u	-	-
PI	0.45 K_u	1.2 K_p/T_u	-
PD	0.8 K_u	-	$K_pT_u/8$
PID	0.6 K_u	2 K_p/T_u	$K_pT_u/8$

Table 2. Ziegler Nichols closed loop results when the motor is out of the water

Control Type	K_p	K_i	K_d
P	1.777778	-	-
PI	1.6	0.8	-
PD	2.844444	-	0.48
PID	2.133333	1.33333333	0.48

Based on Table 2, these values are entered into Arduino coding, and the results are seen. Because the PI control is the best, the Ki values are modified as written in Table 3.

Table 3. Searches for the value of Kp, Ki, and Kd where the sensor detects objects were not in the water

No	PID Parameter			Time	Description
	Kp	Ki	Kd		
1.	1,6	0,2	0	12,72	with slight oscillation
2.	1,6	0,4	0	13,39	with large oscillation
3.	1,6	0,6	0	14,44	with large oscillation
4.	**1,6**	**0,8**	**0**	**12,11**	**with slight oscillation**
5.	1,6	1	0	13	with slight oscillation
6.	1,6	1,2	0	14	with slight oscillation
7.	1,6	1,4	0	13,03	with large oscillation
8.	1,6	1,6	0	15	with slight oscillation
9.	1,6	1,8	0	12,30	with large oscillation
10.	1,6	2	0	13,58	with slight oscillation

Table 3 is the search for Kp, Ki, and Kd values where objects must be detected by the sensor when the motor is not in the water. Thus the sensor used also does not need to be immersed in water. The results of this search produce optimal values for Kp, Ki, and Kd, where the optimal value is Kp = 1.6; Ki = 0.8 and Kd = 0, where the oscillations are tiny at these values, and the time taken to reach the target is relatively small. These values compare the values obtained if the object is actually in the water, so the sensor must also be submerged in the water.

Furthermore, research is carried out when the motor is in the water. The analysis was carried out and obtained the value of when the motor was in the water was. Furthermore, for K_u = 2.66 and Tu = 2.4, K_i and K_d can be obtained based on Table 4.

Table 4. Ziegler Nichols closed loop for sensors in the water

Control Type	Kp	Ki	Kd
P	1.333333	-	-
PI	1.2	0.6	-
PD	2.133333	-	0.36
PID	1.6	1	0.36

Then try to find the best Kp, Ki, and Kd value if the sensor is in the water. Ziegler Nichols closed loop for sensors in the water is shown in Table. 5.

Table 5. Searches for the value of Kp, Ki, Kd where the sensor detects objects in the water

No	Propositional			Time	Description
	Kp	Ki	Kd		
1.	1,2	0,2	0	14,67	Can reach the target
2.	1,2	0,4	0	14,61	Can reach the target
3.	**1,2**	**0,6**	**0**	**14,88**	Can reach the target
4.	1,2	0,8	0	15,17	Can reach the target
5.	1,2	1	0	14,30	Can reach the target
6.	1,2	1,2	0	15,13	Can reach the target
7.	1,2	1,4	0	15,09	Can reach the target
8.	1,2	1,6	0	15,15	Can reach the target
9.	1,2	1,8	0	15,52	Can reach the target
10.	1,2	2	0	15,19	Can't reach the target

From Table 3. and Table 5. the conditions on land and water differ quite significantly. In situations not in the water, the optimal value of Kp=1,6; Ki = 0.8 and Kd = 0, while in the conditions in the water, the optimal value of Kp = 1.2; Ki = 0.6; Kd = 0. The time to reach the target is also different. For conditions on land, it takes 12.11 minutes, while in the water, it takes 14.88 m to reach the target. It confirms that in water, the values of Kp and Ki cannot be as large as on land because there is water blocking.

Future research will try to use the fuzzy logic controller algorithm with sonar sensors. The fuzzy logic controller is expected to be able to adjust the sensor position more accurately and automatically. In contrast, the sonar sensor can detect objects in the water, even though the water is cloudy and the colour of the sediment tends to be dark. It also adds to the repertoire of knowledge of controlling electric vehicles that are activated in water.

4 Conclusion

Arduino as a controller can be used to measure the volume of sediment, with an electronic circuit consisting of Arduino Mega 2560, two BTS 7960 motor drivers, three Adjustable Infrared Sensor Switch, LCD (Liquid Crystal Display) + I2C, PG45 motor, PG28 motor with internal Rotary Encoder, Hitec HS-5625MG servo motor, 24 Volts DC source, and a 5 Volt DC.

The PID algorithm controls the motor in lowering the infrared sensor so that it can be done automatically and immediately stops at a predetermined position. The optimal values if the sensor and the object to be detected were out of the water are Kp=1,6, Ki = 0,8 dan Kd = 0. The optimal values if the sensor and the object to be detected were in the water are Kp=1,2, Ki=0,6, and Kd=0.

The time to reach the target is also different. For conditions outside the water, it takes 12.11 seconds, while in the water, it takes 14.88 seconds to reach the target.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

-Sri Arttini Dwi Prasetyowati coordinated the research, checked the device, controlled the PID program, monitored the process, and made the research results.

-Bustanul Arifin checked the device, gave input about the Arduino program, operated the Arduino program to run the device, and controlled the PID program.

-Akhmad Syakhroni checked the device and monitored the boat mechanic.

Muhammad Khoirun Faza assembles electronic devices in the boat and operates Arduino to run the device.

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