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Development of an Automated Train Braking Control System Using Arduino Uno for Enhanced Community Safety

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Abstract: *The contribution of the railway sector to national transportation remains relatively insignificant. The primary challenges include inadequate infrastructure and insufficient facilities. Additionally, the railway signaling network is ineffective, leading to a high rate of accidents caused by disruptions in train operations. Furthermore, the level of service provided still falls far short of public expectations. However, the rapid advancement of technology offers promising solutions. This progress is evident in various innovations, such as traffic lights, electronic devices, and the internet, which have significantly eased workloads across industries. To address these challenges, the development of an automated railway gate prototype is proposed. This system utilizes a buzzer, servo motor, LCD, LED lights, ultrasonic sensors, and Arduino UNO R3 to automatically manage the opening and closing of railway gates, enhancing operational efficiency and ensuring community safety.*

Keyword*: Arduino, LCD, Servo, ultrasonic, UNO R3*

Introduction

In the current era of technological and transportation advancements, the utilization of control panel systems plays a crucial role as a supporting tool. Without the implementation of control panel systems, technological progress would be difficult to achieve [1]. Control panels serve as the backbone for the operation of various technologies, including microcontrollers, which are instrumental in advancing transportation systems. Examples of control panel applications can be seen in railways, industrial machinery, power plants, and telecommunication systems [2]. Therefore, it is essential for engineering professionals to thoroughly study and optimize the use of control panel systems to enhance their effectiveness and efficiency.

The complexity of control panel systems currently used in various equipment poses a significant challenge, particularly in the transportation sector in Indonesia. This challenge affects transportation across all economic levels upper, middle, and lower classes. The costs associated with maintaining or repairing control panel systems often place a financial burden on stakeholders. Recognizing these challenges, addressing and managing control panel failures more effectively has become a critical necessity. For transportation technology in Indonesia, there is a pressing need for affordable and straightforward systems that can be widely implemented at a reasonable cost [3].

One of the feasible technologies is the automatic control of trains while in motion, which simplifies human tasks and enhances operational safety. At present, numerous accidents are caused by trains, primarily due to the absence

of railway crossing gates and the lack of awareness among road users at unguarded crossings. For instance, a tragic accident occurred in Tulungagung on Sunday, February 27, 2022, involving a tourist bus and a train, resulting in four fatalities. Numerous other accidents at crossings without gates continue to claim lives.

To address this issue, I propose the development of an automatic railway gate system to mitigate the risks associated with train-related accidents. This system is particularly vital for the many railway crossings in Indonesia that lack gates and attendants.

Train accidents, particularly at ungated railway crossings, are alarmingly frequent in Indonesia. The following diagram illustrates the trend in train-related accidents at ungated crossings:

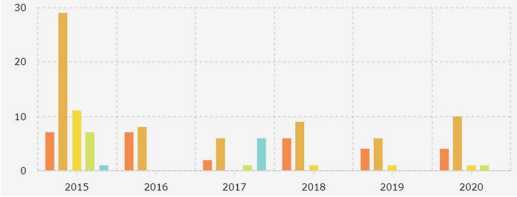

Figure 1. Incident value cause train in indonesia

Based on the above graph, train accidents surged in 2015 but decreased in 2016. However, to further minimize accidents, I propose an additional innovation an automated braking system for trains. This system would activate when a vehicle is detected obstructing the tracks, initiating gradual braking starting from a radius of 600 meters from the obstacle. The braking process would occur in three stages until the train comes to a complete stop. This mechanism is expected to prevent accidents, especially in cases where vehicles become immobilized on the tracks. For example, in Blora Regency on Sunday, May 21, 2017, a Daihatsu Zebra pickup truck stalled on an ungated crossing between Wadu and Randublatung Stations. Fortunately, no casualties were reported in this incident.

Given the above challenges, implementing automated train braking systems and automatic railway gates is imperative for advancing railway technology in Indonesia. These innovations can significantly improve railway safety and operations across the country. This system employs distance sensors and is managed using an Arduino microcontroller, ensuring precision and reliability.
By integrating these technological advancements, the Indonesian railway system can achieve enhanced safety standards, reduced accident rates, and more efficient transportation management.

Methodology

1. Filed Method

The method employed by the author involves direct observation to gather data related to the issues concerning railway crossing gates[4]. The data collection was carried out through various means, with one of the main approaches being observation, where the author directly visited the relevant locations to gather the necessary information [5]. This was done specifically at PT KAI Cirebon, the company responsible

for managing railway operations in the area. Through direct observation, the author was able to access key aspects of the railway crossing system and its operations.

During the observation process, several important pieces of information were gathered [6][7]. The first aspect covered was a general overview of PT KAI Cirebon, providing insight into its role and functions in railway management. Additionally, the author examined the company's vision and mission, which were crucial in understanding its long-term goals and strategic objectives. The organizational structure of PT KAI Cirebon was also analyzed to see how different departments and units collaborate to manage the railway system efficiently.

The most critical data collected from the observation was related to the functioning of the railway crossing gate system currently in place. By examining how the system operates, the author was able to identify potential challenges and gather relevant insights on its effectiveness[8][9]. This direct observation of the railway crossing gates provided valuable information that will contribute to a better understanding of the system's current performance and areas for improvement.

2. Library Method

The activity of referencing several books related to PT KAI Indonesia, particularly those relevant to the operations conducted at PT KAI Cirebon, aims to provide a solid theoretical foundation for the research. These references are gathered from available books and literature in the library, including lecture materials, as well as data collected through online resources[10][12]. This includes electronic journals and documents accessible via search engines, all of which contribute valuable insights for the research process[11].

Following the observation and interviews conducted with PT KAI Cirebon, several issues regarding the railway crossing gates were identified. The first issue is the frequent occurrence of accidents due to delays in closing the railway crossing gates. This delay poses a significant safety risk, as it increases the likelihood of collisions between vehicles and trains. Another issue is that the current railway crossing gate system still relies on manual operation, which can lead to inefficiencies and potential errors. Additionally, the gate attendants are not always available to monitor the gates 24/7, which adds to the problem, as it means there is no continuous oversight to ensure the gates function properly and safely.

These identified problems highlight the need for improvements in both the technology and the operational procedures at PT KAI Cirebon. Addressing the manual system, ensuring more consistent monitoring, and implementing solutions to prevent delays in closing the gates will be critical in enhancing safety and efficiency at the railway crossings. These findings serve as the foundation for further analysis and potential solutions to improve the current system.

3. Functional Analytic

The system being developed is an automatic railway crossing gate system based on Arduino Uno, utilizing an ultrasonic sensor[13][14]. This system is designed to automate the process of opening and

closing railway crossing gates, which is typically a manual task, thereby improving efficiency and safety. By incorporating this technology, PT KAI Cirebon aims to streamline operations and reduce the risk of accidents caused by delays in closing the gates. The ultrasonic sensor plays a key role in detecting the presence of trains, triggering the automatic operation of the gate.

User analysis is an essential part of understanding who will interact with the system, ensuring that appropriate security measures are in place and that users are properly equipped to operate the system. This analysis helps determine the level of understanding and familiarity users will need to effectively engage with the automated railway crossing gate system[15]. The users who will operate the system include two main groups: the gate attendants, responsible for overseeing and ensuring proper function, and the employees or staff of PT KAI Cirebon, who will be involved in monitoring the system's performance and managing any issues that may arise.

It is crucial for both gate attendants and PT KAI Cirebon employees to have adequate training and understanding of how the system works. This will ensure smooth operation and minimal disruption to the automated system [16]. Additionally, the security and safety protocols for handling the system must be clear to these users, guaranteeing that any potential malfunctions or emergencies are handled quickly and effectively. By analyzing the users, PT KAI Cirebon can ensure that the new automated railway crossing gate system is operated safely and efficiently.

4. Software

Overall, this system uses an Arduino Uno microcontroller, which has been programmed using the C programming language to control the automatic railway crossing gate system[17]. The Arduino Uno serves as the central processing unit that interprets the data from the sensors and actuates the necessary actions, such as opening or closing the gates based on the presence of a train. The system's functionality is entirely dependent on the successful integration of both hardware and software components[18].

The software required for developing the prototype of this automatic railway crossing gate system includes several tools. First, Arduino UNO is used to create and upload the control program that governs the system's behavior [19]. The microcontroller reads input from the sensors, processes the data, and then triggers the gate's automated response accordingly. The second essential software tool is Fritzing, which is used to design and visualize the hardware circuit diagrams during the system's design phase. Fritzing helps in creating block diagrams of the circuit layout, making it easier to understand and implement the hardware connections needed for the system to function properly [20].

Together, these tools and components form the foundation of the automatic railway crossing gate system, ensuring that it operates efficiently, securely, and reliably. The integration of Arduino Uno for control

and Fritzing for design plays a crucial role in the system's successful implementation, providing both the logic and the visual representation needed for effective development and troubleshooting.

5. Hardware

In the development of the automatic railway crossing gate prototype based on Arduino Uno using an ultrasonic sensor, several hardware components are required for the system's operation. These components include:

1. Arduino Uno with Atmega328 microcontroller: This acts as the controller for the automatic railway crossing gate system. The Arduino Uno processes inputs from the ultrasonic sensor and controls the system's actions, including the opening and closing of the gate.
2. Ultrasonic Sensor: The ultrasonic sensor is crucial for detecting the arrival of a train. This sensor measures distance by emitting sound waves and calculating the time it takes for the sound to bounce back. The data from the sensor is used to determine the presence of a train and trigger the appropriate actions in the system.
3. Servo Motor: The servo motor functions as the actuator to open and close the railway crossing gate. It responds to commands from the Arduino, rotating to either lift or lower the gate depending on the situation.

Automatic Railway Crossing Gate Circuit

1. System Activation: When the prototype is powered on, the ultrasonic sensor is connected to the system, and the system is activated by the user. The system then enters a standby mode, awaiting input from the sensor.

2. Train Detection: If the sensor detects the presence of a train (based on distance measurements), the system processes this input and displays the train's arrival status on an LCD screen. This provides real-time information to the operator.

3. Gate Operation: When the ultrasonic sensor detects the arrival of a train, the system activates the servo motor to close the railway crossing gate. Conversely, when no train is detected, the system can open the gate by commanding the servo motor to rotate in the opposite direction.

This process ensures that the railway crossing gate operates automatically and efficiently, minimizing the need for manual intervention while improving safety and response times at railway crossings.

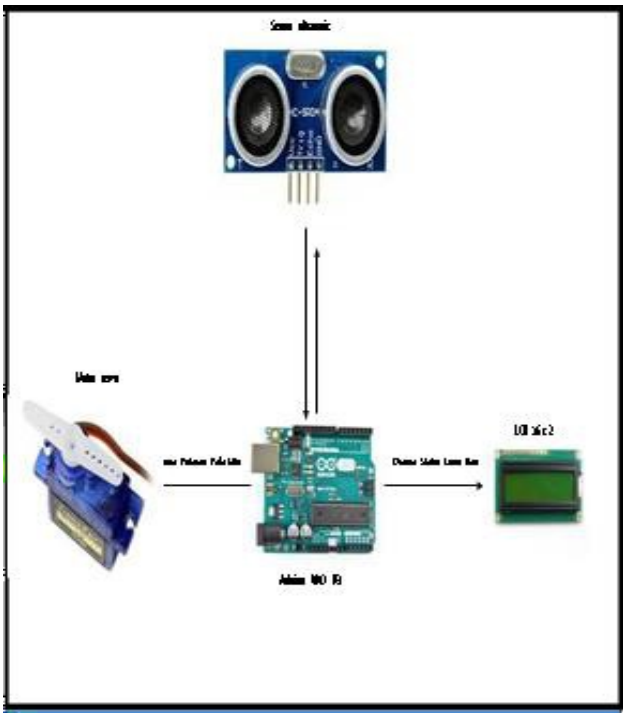

Figure 2. Hardware integration

Results and Discussions

1. Ultrasonic

Table 1. Ultrasonic sensor

No	Level (cm)	Level sensor Ping (cm)
1	5	5
2	6	6
3	7	7
4	8	8
5	8	8

Based on the test results of the HC-SR04 ultrasonic sensor in table 5.1 above, it can be concluded that the sensor detects the height of the train based on the measured level.

2. Servo

This servo test aims to find out how effective the servo speed is in making movements (in the form of angles. This movement is caused by the wheels in the servo. This servo test is carried out from an angle of 0 degrees to 180 degrees with an initial state of 180 degrees.

Based on the results of the alarm research in table 5.2, the LED and buzzer will light up based on the height of the train detected by the ultrasonic sensor and in accordance with the program that has been designed and created in the Arduino Uno sketch.

Table 2. Servo Motor

No	Angle servo	Trial 1	Trial 2	Trial 3	Average second
1	0	0,87	1	0,96	0,94
2	45	0,92	0,83	0,87	0,87
3	90	1	1	0,87	0,95
4	180	0	0	0	0

Based on the servo test results in table 2 above, it can be concluded that the servo which is initially at a 180 degree angle can move towards certain angles with an average speed of 0.92 seconds.

3. Integration hardware

This hardware test is to find errors or deficiencies in the Arduino UNO R3 based automatic train doorstop prototype using the HC-SR04 ultrasonic sensor. especially in the hardware components used in building the system.

Table 3. Integration result

No	Sensor *ultrasonic* (cm)	LED	Buzzer
1	0< distance <3	On	On
2	3< distance <5	On	On
3	5< distance <7	On	On
4	7< distance <9	On	On
5	distance >9	Off	Off

Conclusion

Based on the findings and discussions conducted, the conclusions regarding the

title "Development of an Automated Railway Gate Prototype Based on Arduino UNO R3 Using HC-SR04 Ultrasonic Sensor" are as follows:

1. The HC-SR04 ultrasonic sensor successfully detects the approaching train, integrated with the Arduino UNO R3 microcontroller, using the C programming language for effective control.
2. The automated railway gate prototype, based on Arduino UNO R3 and utilizing the HC-SR04 ultrasonic sensor, was designed and developed using the Prototype Methodology, ensuring practical functionality and efficient implementation.

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