Automatic Railway Barriers Security System Design using Inductive Proximity Sensor based on Atmega 328

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Abstract: The railroad-crossing gate is a safety measure for the passing train. Often accidents occur at the point of railroad-crossing, due to the negligence of officers in opening the gate and bad ethics from other transportation users. Therefore, it is necessary to use the automatic railroad-crossing gate as a security system. The automatic railroad-crossing gate was made using a train imitation as a prototype of a real train, Atmega328 microcontroller, inductive proximity sensor and DC servo motor. The output of this device was opening and closing the train door and the measurement of train speed. The experimental method was used in this study. The observation was used to find out the results of train detection. In addition, the measurement of train speed from the system was compared with manual measurement of speed. The tests were repeated for 10 times. The automatic train crossbar was able to detect trains coated with metal, while the train which is not coated metal could not be detected. The system was being able to display the measurement of the speed of the train. However, there is a difference in the speed of manual calculation by the researcher as much as 1, 3 cm / s. The difference was caused by the operation of the stopwatch in data collection process.

1 INTRODUCTION

In the modern era, technology is growing rapidly, many technologies have been invented along with the development of the era. The existing technology and the newly invented technology can be combined to produce more sophisticated technology to facilitate human needs. In land transportation such as trains, trains are rail transportation consisting of a series of carriages pulled along the railroad to transport passengers and goods. Train is classified as an efficient land transportation, because it can transport passengers and goods faster than other land transportation.

Trains are a very influential land transportation in the future, because trains are one of the land transportation that is often used by the public. According to data from the Central Bureau of Statistics, 29,328 passengers were located in the island of Java in December 2015 and has increased every year, as of November 2017 train passengers reached 33,798 passengers (bps.go.id).

The point of intersection of the road between the railroads is commonly referred as the railroad - crossing of a railway line, a railroad crossing that is when the railroad intersects with the road (Regulation of the Director General of Land Transportation SK.770 / KA.401 / DRJD / 2005). The following is data on railway level crossings on the island of Java shown in Table 1.

Table 1. The list of level crossings on the island of Java.

No.	Partial Crossing	Amount
1.	Guarded Crossing	969
2.	Unattended Crossing	2923
3.	Wild Crossing	410
Total		4302

With the large number of the railroad - crossing on the Java and the number of unattended and illegal the crossing road, train accidents have become a major factor at the level crossing. Due to the number of accidents that often occur at railway crossings, it is necessary to create a railroad gate to warn other land transportation users, they can stop before the railroad gate to give the train a chance to run as stated in (Law of the Republic of Indonesia No. 72 of 2009 regarding Railway Traffic and Transportation). The automatic

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railroad-crossing gate is not only to replace human's job as a crossing guard, but also to reduce the costs that must be incurred for the salary of the crossing road guard. The automatic railroad-crossing gate is also prioritized to maintain railroad crossings without guard posts. The previous studies on the automatic railroad-crossing gate have used the automatic railroad-crossing gate using infrared sensors (Sarnia and Yusnita, 2015), (Kumar et al., 2017), (Krishnamurthi et al., 2015), (More et al., 2015), (Pangestu., 2017: 282-291). Detection using ultrasonic sensors has also been performed (Firdaus, 2016) and optocoupler sensors (Santoso et al., 2013), (Banuchandar et al., 2012). Furthermore, the motion detection has also been installed on the detection system (Fayyadh et al., 2015). The results of the detection of infrared and ultrasonic sensors are very sensitive. Therefore, it has not been optimal in detecting trains. While, the results of detection using motion detection are not optimal because the results of the study are affected by the condition of light.

With some shortcomings of the previous studies which are very sensitive to passing objects, sensors that can detect trains specifically metal or iron to detect trains are needed, because most cars passing the railroad are made of metal or iron, with that The research employed proximity inductive sensors atmega328. This present study investigated these following aspects:

1. Proximity sensor as a detection of train arrival, so that train detection can be more specific (can only detect objects made of metal)
2. Train speed measurement system as the information for vehicles crossing the railroad.

The aim of this study was to design a more specific train detection system.

2 METHOD

The experimental method was employed in this study. According to Jaedun (2011: 5), the experimental method is causal study whose evidence is obtained through comparison / comparison between these following things:

a. The experimental group (which receives treatment) with the control group (which does not receive treatment); or

b. Subject condition before being given treatment with after being given treatment.

Experimental study is also a study conducted intentionally by researchers by giving a certain treatment / to the subject of the study in order to generate an event / situation that was examined what are the consequences. The procedure of this study can be seen in Figure 1.

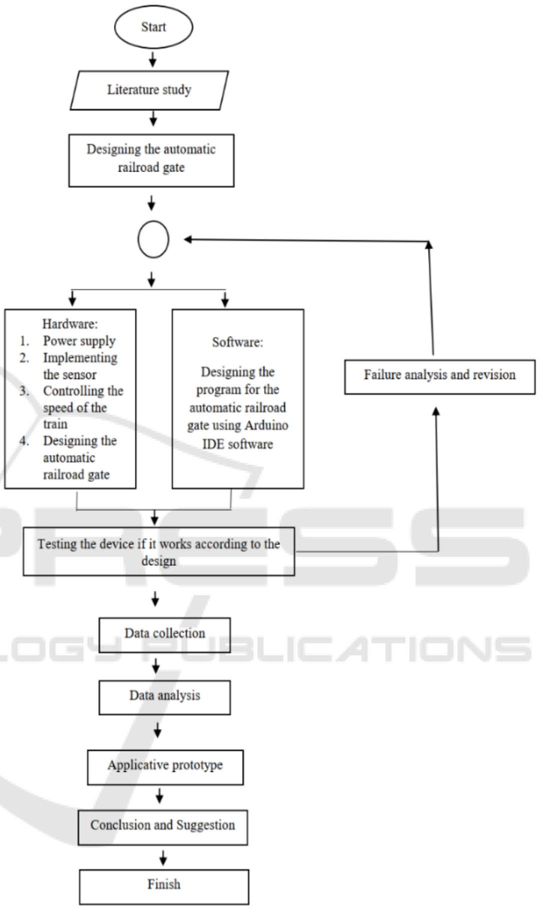

Figure 1: the procedure of the study.

2.1 Arduino Uno

Arduino Uno is an arduino board that uses an ATmega328 microcontroller. The Arduino Uno has 14 digital pins (6 pins can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power supply connector, an ICSP header, and a reset button. Arduino Uno uses ATmega16U2 which is programmed as a USB-to-serial converter for serial communication to a computer via a USB port. The physical form of arduino uno is shown in Figure 2 (Suyatno et al: 2017).

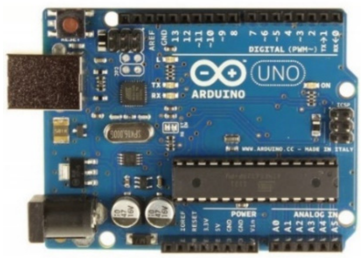

Figure 2: Arduino uno.

2.2 Inductive Proximity Sensors

Figure 3 Inductive proximity sensor.

The detection of the presence of a train employed an inductive proximity sensor. The inductive proximity sensor combined an electromagnetic coil used to detect the presence of a conductive metal object. The sensor ignored the objects that were not of metal. An inductive sensor as shown in Figure 3 is a non-contact electronic switch. Inductive sensors are used to detect metals and graphite. Sensors were used for these following things: monitoring and measuring speed speed, sensing the final position and pulses of engine rotation (Miftahu, 2013: 258-261) .

2.3 DC Servo Motor

Servo motors are DC motors as appeared in Figure 4 that have high quality. This motor was equipped with a control system. In its application, servo motors were often used as closed loop controls. As a consequence, they can handle position changes accurately as well as speed and acceleration settings. Servo motor wiring system consisted of three parts: Vcc, Gnd, and Control (PWM). (Dr. Widodo Budiharto, 2013: 81-82)

Figure 4 DC Servo Motor.

2.4 Sensor Placement Design

Figure 5 shows the sensor placement design. The sensor design placement to the passing train, the inductive proximity sensor was placed on top of the bar and faced the ground. Therefore, the sensor did not get interference from other objects which caused the railroad crossing bar to close even though there were not trains passing by, the sensor placement design can be seen in figure 5.

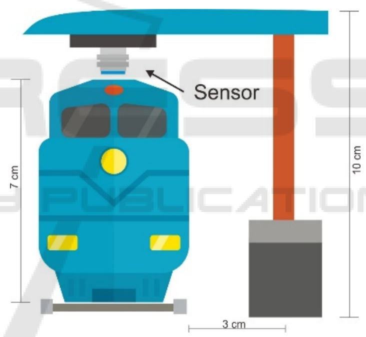

Figure 5 Sensor placement design.

2.5 The Design of the Railway

The security system design of the railway-crossing bar employed a mock train as the object, using three inductive proximity sensors as the main sensors. Each sensor had a distance from the railway-crossing bar and each function for the system. The door bar will be driven by a DC servo motor, the design of the design can be seen as shown in Figure 6.

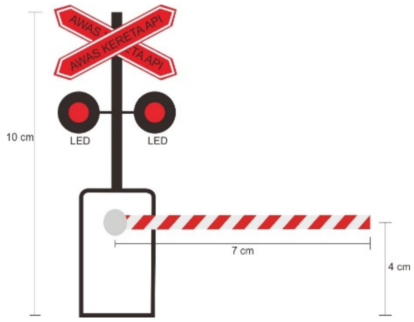

Figure 6: The design of the door bar

2.6 Railroad-crossing Bar Design

The railroad - crossing bar as appeared in Figure 7 was the safeguard used at a railway crossing to close the train track. According to the Regulation of the Director General of Land Transportation SK.770 / KA.401 / DRJD / 2005, the railroad - crossing bar must be equipped with

1. A flashing red LED signal or two red LED lights that turn one alternately,
2. The sound signals or sign on lights that indicate the direction of the train's arrival.

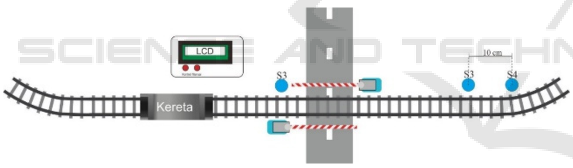

Figure 7. The design of railroad-crossings in this study.

3 RESULT AND DISCUSSION

The design of the system in this study consisted of the manual and automatic system. The design of manual system can open and close the railroad gate according to the command of the manual button. The automatic design system can work automatically without the need for commands from the humans or guard of the railroad – crossings. The railroad – crossing gate can open and close automatically using three inductive proximity sensors.

The design of the automatic railroad – crossing gate had two railroad tracks that expand for 30 cm, and have two railroad tracks that form a semicircle with the diameter of 36 cm. So, the length of the railroad track can be calculated by the following formula:

$$\textbf{The length of track} = 30 \times 2 + \pi \times d$$
$$= 60 + 3.14 \times 72$$
$$= 286 \text{ cm}$$

Circling the railroad tracks with the length of 286 cm took around 13 seconds. Therefore, the train speed can be determined as follows:

$$v = s / t \rightarrow 286/13 = 22 \text{ cm / s}$$

To operate the automatic system, the distance of the sensor placement to the railroad crossing gate must be determined, with the waiting time of the system after the train is detected by sensor 1 until it reaches the gate for 5 seconds, with a train speed of 22 cm / s, then the distance of the sensor placement can be calculated as follows:

$$s = v \times t \rightarrow 22 \times 5 = 110 \text{ cm}$$

The distance of 110 cm is a predetermined distance from the railroad gate until the placement of the first sensor. The time for the detection of the first sensor 1 until the second sensor was 1.5 seconds. The time required for the railroad-crossing bar closed until the train reached the railroad-crossing bar was 3.5 seconds.

The distance of the sensor placement to the crossing of the actual train crossing with the fastest train on the island of Java is 80 km / hour based on the data on train-api.info page (22 April 2015). The website shows that the speed of the fastest trains operating on the island Java is Argo Sindoro train (Gambir - Semarang) with the speed of 445 km / h. The train took within 5 hours 30 minutes from Gambir to Semarang. The desired time when sensor 1 detects the train is 5 minutes. It takes 1 minute 30 seconds for the sensor to detect the train, and 3 minutes 30 seconds then the train reaches the train crossing. The sensor placement can be determined as follows:

Sensor 1 detects trains

$$t = 5 \text{ minutes} = 0.083$$
$$\text{then, } s = v \times t \rightarrow 80 \times 0.083 = 6.64 \text{ km}$$

Sensor 2 detects trains
t = 3 minutes 30 seconds = 0.058
then, s = v × t → 80 × 0.058 = 4.64 km

then from the calculation of the formula it can be seen that the distance between sensor 1 and sensor 2 is 2 km.

3.1 Functional Test Results of the Inductive Proximity Sensor

Functional test of inductive proximity sensor aims to determine the level of accuracy of the sensors in detecting trains. The tests were conducted 20 times. 10 tests used metal-coated trains and 10 tests used non - metal coated trains. Each test was carried out by giving a different distance between the sensor and the train. Different distances between sensors and trains were aimed to find out the maximum range of the inductive proximity sensor. Table 2 shows functional test results of the inductive proximity sensor.

Table 2. Functional Test Results of the Inductive Proximity Sensor.

No.	Distance	Train	Detection results
1.	0.1 mm	Metal coated	Detected
2.	0.1 mm	Without metal	Not detected
3.	0.2 mm	Metal coated	Detected
4	0.2 mm	Without metal	Not detected
5.	0.3 mm	Metal coated	Detected
6.	0.3 mm	Without metal	Not detected
7.	0.4 mm	Metal coated	Detected
8.	0.4 mm	Without metal	Not detected
9.	0.5 mm	Metal coated	Not detected
10	0.5 mm	Without metal	Not detected
11.	0.6 mm	Metal coated	Not detected
12	0.6 mm	Without metal	Not detected
13.	0.7 mm	Metal coated	Not detected
14.	0.7 mm	Without metal	Not detected
15.	0.8 mm	Metal coated	Not detected
16.	0.8 mm	Without metal	Not detected
17.	0.9 mm	Metal coated	Not detected
18.	0.9 mm	Without metal	Not detected
19.	1 cm	Metal coated	Not detected
20.	1 cm	Without metal	Not detected

3.2 The Functional Speed Test Results and Train Speed Measurements

The functional tests of the train's speed and speed measurements were performed to determine the speed control performance and if the train speed measurement can function properly. Potentiometer 10 K 10 has been installed on the toy train, the testing was performed for 10 times by changing the predetermined resistance values: 10 KΩ, 9 KΩ, 8 KΩ, 7 KΩ, 6 KΩ, 5 KΩ, 4 KΩ, 3 KΩ, 2 KΩ, 1 KΩ on the potentiometer to determine the difference in speed.

The functional test of train speed measurement was conducted by using the design that has been designed to detect train speed. This test was conducted to determine the accuracy of the system in measuring the speed of the train. The train speed measurements generated from the system were compared to the manual train speed measurement using the calculation of this following formula $v = \frac{s}{t}$ where s is the predetermined distance, the distance between sensor 1 and sensor 2 is 30 cm, while t is the time taken by the train to travel from sensor 1 to sensor 2, in the calculation of the travel time from sensor 1 to sensor 2 manually, the resulting time was taken using the stopwatch. Table 3 shows the results.

Table 3. The Results of speed testing and train speed measurement.

No.	Resistance	Voltage (Theory)	Voltage (system)	Speed Measurement (theory)	Speed Measurement (system)	Difference
1	10 KΩ	3 V	2.9 V	22 cm / s	21.7 cm / s	0.3 cm / s
2	9 KΩ	2.7 V	2.7 V	20.5 cm / s	20.4 cm / s	0.1 cm / s
3	8 KΩ	2.4 V	2.4 V	19.3 cm / s	19.5 cm / s	0.2 cm / s
4	7 KΩ	2.1 V	2 V	18 cm / s	18 cm / s	0 cm / s
5	6 KΩ	1.8 V	1.7 V	16.9 cm / s	16.7 cm / s	0.2 cm / s
6	5 KΩ	1.5 V	1.5 V	15.2 cm / s	15.1 cm / s	0.1 cm / s
7	4 KΩ	1.2 V	1.2 V	14.5 cm / s	14.5 cm / s	0 cm / s
8	3 KΩ	0.9 V	0.8 V	13 cm / s	12.9 cm / s	0.1 cm / s
9	2 KΩ	0.6 V	0.6 V	12 cm / s	11.9 cm / s	0.1 cm / s
10	1 KΩ	0.3 V	0.3 V	10.5 cm / s	10.7 cm / s	0.2 cm / s

3.3 The Results of the Performance Test of the Design System

Testing of the design of the automatic railroad – crossing gate system was an overall test of the design system. The testing of the design was conducted to determine the performance of the automatic railroad – crossing gate system. The overall design testing was carried out by running the system according to the program, namely by passing the train through sensor 1, sensor 2, and sensor 3 by testing it for 10 times with a fixed and unidirectional train speed. This test was conducted to find out the feasibility of the automatic railroad – crossing gate system. The result of the performance test of the design system explained in Table 4.

Table 4. Test results of the Work Design system.

No.	Train Condition	Train passes	The gate system	LCD display	*Buzzer*
1.	Metal – coated Trains	Sensor 1	Open	"Watch out for trains"	ON
		Sensor 2	Closed	"Train speed"	ON
		Sensor 3	Open	"Please walk"	OFF
2.	Non Metal – coated Trains	Sensor 1	Open	"Train crossing"	OFF
		Sensor 2	Open	"Train crossing"	OFF
		Sensor 3	Open	"Train crossing"	OFF
3.	Metal – coated Trains	Sensor 1	Open	"Watch out for trains"	ON
		Sensor 2	Closed	"Train speed"	ON
		Sensor 3	Open	"Please walk"	OFF
4	Non Metal – coated Trains	Sensor 1	Open	"Train crossing"	OFF
		Sensor 2	Open	"Train crossing"	OFF
		Sensor 3	Open	"Train crossing"	OFF
5.	Metal – coated Trains	Sensor 1	Open	"Watch out for trains"	ON
		Sensor 2	Closed	"Train speed"	ON

No.	Train Condition	Train passes	The gate system	LCD display	*Buzzer*
		Sensor 3	Open	"Please walk"	OFF
6.	Non Metal – coated Trains	Sensor 1	Open	"Train crossing"	OFF
		Sensor 2	Open	"Train crossing"	OFF
		Sensor 3	Open	"Train crossing"	OFF
7.	Metal – coated Trains	Sensor 1	Open	"Watch out for trains"	ON
		Sensor 2	Closed	"Train speed"	ON
		Sensor 3	Open	"Please walk"	OFF
8.	Non metal – coated Trains	Sensor 1	Open	"Train crossing"	OFF
		Sensor 2	Open	"Train crossing"	OFF
		Sensor 3	Open	"Train crossing"	OFF
9.	Metal – coated Trains	Sensor 1	Open	"Watch out for trains"	ON
		Sensor 2	Closed	"Train speed"	ON
		Sensor 3	Open	"Please walk"	OFF
10	Non Metal – coated Trains	Sensor 1	Open	"Train crossing"	OFF
		Sensor 2	Open	"Train crossing"	OFF
		Sensor 3	Open	"Train crossing"	OFF

3.4 Discussion of the Functional Test Results of Inductive Proximity Sensors

The results of the functional test of inductive proximity sensor showed that the inductive proximity sensor can only detect objects made of metal. While, the sensor cannot detect the passing train that was not coated with a metal. The inductive proximity sensor could only work with the distance of sensor to the train = 0.1 mm - 0.4 mm, at a distance of 0.5 mm - 1 cm inductive proximity sensor could not detect the train. Therefore, the maximum detection distance of the inductive proximity sensor is 0.4 mm. This detection distance in line with the datasheet on the inductive proximity sensor which stated that the sensor can only detect metal objects with a maximum detection distance of 0.4 mm.

3.5 Discussion of Functional Test Results of Speed and Train Speed Measurement

From the data regarding train speed control, the results showed that the train could be controlled by using a potentiometer. The test was performed by varying the potentiometer resistance value from the highest resistance value to the lowest resistance value, the train speed can change from fast to slow. From the results of train speed testing, the highest train speed was at 10 KΩ potentiometer resistance, a voltage on a dc motor of 3 V and has a measured system speed of 21.7 cm / s with the theoretically measured speed is 22 cm/s. On the other hand, the lowest train speed is at 1 KΩ, the voltage on the dc motor is 0.3 V and has a speed of 11 cm / s while the theoretical measurement is 10.9 cm / s.

The test on the train speed measurement revealed that there is a difference in the error on the train speed measurements measured by the system with the theoretical train speed measurement. The average of difference in the measurement results by the system and theory is 1.3 cm / s. The difference from the results was obtained from the calculation of the speed formula using the sensor then it was inputted into the program and processed by arduino uno microcontroller compared to theoretical speed measurement by using a stopwatch. The difference was caused by the operation of the stopwatch during the manual train speed measurement.

3.6 Discussion of Research Results of the Overall Performance of the Design

The results of study revealed that the automatic railroad-crossing gate could work according to the expected system design. The test was carried out by using a metal-coated and a non metal – coated train for 10 times. The automatic railroad-crossing gate opened and closed the gate manually and automatically according to the programmed system. The system could only detect the metal-coated trains. When sensor 1 detected the train then the *buzzer* was active. The system started calculating the travel time of the train until it reacheed sensor 2 and the LCD displayed "watch for the train". When sensor 2 detected the train, it began calculating the travel time from sensor 1 to sensor 2 and started opening the gate and LCD displayed the results of train speed measurement as "Train speed". When sensor 3 detected a train, the system waited until the train was not detected as a sign the train has passed, then the gate of the railroad - crossing opened and the LCD displayed "please walk".

4 CONCLUSIONS

The design of the automatic railroad – crossing gate using inductive proximity sensors based on atmega328 could perform optimally. The results of the inductive proximity sensor test showed that sensor detection can only detect metal – coated object and the maximum detection distance is only 4 mm. The results of adjusting the train speed using a potentiometer can also work well and the train speed measurement system obtained more accurate results compared to manual calculations. The results showed that the system and manual speed measurements had an average difference of 1.3 cm / s. The overall performance testing of the design system showed that the system could work optimally. This design has a manual operation to open the gate manually when you want to open the gate manually during a system failure.

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