Development of Radar-based Sensor System for Smart Level Crossing Technology

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Abstract. This research focuses on the development of Smart Level Crossing for preventing the accidents in the level crossing by detecting train at a certain distance before reaching the train gate inside the level crossing area. In order to detect the train in the level crossing, sensors for detecting train and communication systems that sends data to the train gate must be determined. This research tries to utilize a radar-based sensor as main part for train detection. This system would communicate with the micro-controller to accordingly carry out the gate closing and opening operations. Warning lamp and warning light would be present to warn off pedestrians that use level area crossing. Manual back up system will replace the automatic system in the case of smart level crossing system sensor fail to trigger.

1. Introduction

The level crossings handled by the local government in Indonesia are quite large. Level crossing increasing by time and become serious problem both railway and road safety. Most of the accident occur due to manual level crossing and un-maned gates. Many peoples die and huge number get injured over the accident, it becomes government responsibility, and become social expense burden [1, 2].

Usually the level crossing is guarded by an officer if it is considered traffic on the level crossing is quite busy. In this regard, to assist and ease the task of supervisors in the field, the development of early warning equipment becomes something that is needed, to minimize accidents [3].

Smart Level Crossing (SLC) is system that developed for safety and early warning technology at railway level crossing. The system can detect train arrival of the train at certain places, informed to the next gate of railroad crossing, and cannot disturb the current railway system.

Current manual level crossing system technology must be replace using automatic system. Simple technology like IR sensor, radar sensor, IoT technology [4, 5, 6]. The mechanism is very much programming based. The basic idea of smart level crossing system is capturing the arrival of train using radar sensors, send the signal to the micro-controller and active warning vms and light. Manual system still as a backup alongside automatic system in the case of system fail.
2. Related Work
This research goal is to detect train based on radar sensor, send the information to the main control, and passing it to the Variable Message Sign and warning. Many researcher has develop similar technology, especially radar-based sensor technology for railways system of automation. In this section, paper that related to this research will be investigated as part of develop of the Smart Level Crossing (SLC) technology.

Medina et al. [7] focus on research about detected vehicle inside level crossing area by utilizing radar as main sensor. The system was installed at level crossing and two radar units aimed at the crossing from opposite quadrants, measure accuracy of detecting and missing vehicle. However, this research is aiming train detection at certain distance from gate crossing, and the information of existence of train delivered to the pedestrians that across level crossing area.

Another researcher [8, 9, 10] focus on the safety level crossing area and detected obstacle is one of the goal to reach the safety system. By deploy radar-based sensor inside level crossing area, the system can inform the situation to the railways centre system as part of safety confirmation. This research adapt the safety goal, but in Indonesia railway system is difficult to pass the information to the railways system. To adapt this situation, independent radar sensor must be develop to make sure the train signaling secure from another sub-system.

3. System Architecture and Integration
3.1. System Design
Figure 1 is general Design of the system. The detail of each process;

- Radar sensors capture the picture of train from railway area.
- The information of detected train send to the instrument box to process
- The information of train exist send to the box instrument.
- Data that received from box instrument directly sending to the warning light.
- Another subsystem send data to the server.
- Server side application do the processing and send information to the variable message sign.

![Figure 1. General Design Smart Level Crossing](image-url)
Based on the design of prototype SLC model, the system process can be explained:

- **System Input**
  System input related to the sensor that can detect the position of the train.

- **Data Processing**
  Passing data input to the micro-controller, communication device active sending the information to the output target.

- **System Output**
  Process data from control box as information to the Alarm/Alert, Variable Message Sign (VMS), and to the mechanical system of the train gate at the level crossing area.

### 3.2. Hardware Specification

System hardware used in this research can be explained as follows:

#### 3.2.1. Radar Sensor

Radar sensor is the main sensor to detect the existence of the train at the railway track. The type of radar sensor utilized in this research is Radar Sensor R-Gage from Banner Engineering. Figure 2 shows the type of radar sensor R-Gage. This sensor emits a well-defined beam of high-frequency radio waves from an internal antenna. This emitted energy reflects off of a retro reflective target and returns to the receiving antenna. If an object blocks radio waves, the output will turn on like Figure 3. The distance range for the retro reflective target can be configured via remote teach wire. Objects beyond the retro reflective target are ignored (also called background suppression). Radar sensors can do specific range detection, detect objects up to a specified distance, ignoring objects beyond the set point and resulting in higher accuracy. Radar sensors also remain immune to ambient weather conditions not affected by conditions such as wind, rain, fog, light, humidity, and air temperature. This results in accurate detection in outdoor environments. Another advantage is flexible mounting, does not need to be mounted on the train track, installation and maintenance are safer and easier compared to other sensing technologies.

![R-GAGE Radar-Based Sensors](image)

#### 3.2.2. Micro-controller

Arduino micro-controller is used to process the data received from R-Gage radar sensors. Arduino is an open-source electronics platform based on easy-to-use hardware and software. It’s intended for anyone making interactive projects. Arduino senses the experimental area receiving by sensor and triggers another sensor, actuator, and motor. This research utilizes Arduino as control processing unit that processes train existence data from radar, passing data to the server, and control for viewing VMS messages.

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1. https://www.bannerengineering.com/be/en/products/part.79025.html
2. https://www.arduino.cc/
Figure 3. Sensor detects radio waves reflected

Table 1. Arduino Specification

| Specification          | Value        |
|------------------------|--------------|
| Operating Voltage      | 5V           |
| Input Voltage (recommended) | 7-12V     |
| Input Voltage (limits) | 6-20V        |
| Digital I/O Pins       | 14 (of which 6 provide PWM output) |
| Analog Input Pins      | 6            |
| DC Current per I/O Pin | 40 mA        |
| DC Current for 3.3V Pin| 50 mA        |

3.2.3. Relay Module: A relay is a switch that can be turned on or off, decided of the data to pass, controlled low voltages, like 5V Arduino pins. Controlling a relay module with the Arduino can pass the data train from radar-sensor.

3.3. Pseudo-Code for SLC Data Flow

Algorithm 1 show the general data flow of the system

Algorithm 1 SLC Data Flow

1: Radar sensor capture image of train
2: if (sensorState1 == LOW & sensorState2 == LOW) then
3:   Train detected
4:   Data send to box instrument
5:   end if
6: Box instrument distribute data
7: if ArduinoDataReceived == True then
8:   Sending data to warning light
9:   Sending data to the server
10: end if
11: Server processing the data
12: Information send to VMS

4. Result

4.1. System Configuration

The main part of prototype system consist; Power supply 12 Volt, Sensor Radar R-Gage, Mechanical Relay, Micro-controller. Micro-controller connected to the VMS, warning lamp, and
warning speaker.

![System configuration of smart level crossing](image)

**Figure 4.** System configuration of smart level crossing

SM is entrance radar sensor that detect train when enter the area of radar monitored. Four sensor dispatched $SM_{1A}, SM_{1B}, SM_{2A}, SM_{2B}$. SL1, SL2 are pass radar sensor that capture pass train near area of level crossing. Pass sensor near these area box instrument installed that consist micro-controller, vms, and warning light.

### 4.2. Integration and Testing

Integration and testing process follow as

- Re-engineering VMS system that existing and follow industrial standard. VMS show the running text as warning for the pedestrian and vehicle user.
- Configure warning speaker dan warning lamp for vms backup. Voice from warning speaker will will sound continuously as long as the train crosses the crossing and will stop if the train has crossed the crossing. While the warning lamp give a warning to road users in the form of lights that blink as long as the train crosses the crossing.
- This is important part of integration, configure main controller for control and do the coordination to other part of system. Main controller will receive data from $SM$, $SL$ sensor, and send data to the vms, warning speaker and warning lamp.
- Configure front sensor ($SM$) and validation sensor ($SL$) as main sensor that detected train and pass data to the main controller.

Figure 5 show the preparation of the system before dispatching to the area experiment.

### 4.3. Experiment Result

Figure 6 show the position of dispatching sensor aside of railway track. Radar sensor powered from solar system electricity. Main controller, vms, and warning powered from officer building at level crossing area.

Table 2 show the result of experiment of the whole system. The result show that all of the system and subsystem can satisfied this research goal.
5. Conclusion and Discussion

5.1. Conclusion
This research utilize radar sensor to build Smart Level Crossing technology. Radar sensor work on specific range detection, immunity to ambient weather conditions, and flexible mounting. Solar system electricity is main part for powering both radar sensor and micro-controller. The result of experiment show that all of the system and subsystem running well, and satisfied this research goal.
5.2. Discussion

Initial development of smart level crossing technology using vibration and voice sensor but the result were not satisfy this research expected. After change the sensor to the radar-based, the result is become better. Future development of this research are providing data to the mechanical gate system as important part of level crossing technology and utilizing another sensor technology as comparison to the radar-based sensor. Consideration of sensor replacement is due to the comprehensive result of this system show that radar sensor work well detected passenger train but sometimes fail to detect freight train.

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