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Signal Warning Detector (SWAD) for Sustainable Working Environment at Highways

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Abstract: Work environment in highway construction are hazardous due to the particular dynamic and limited workspace availability. Within highway work zones, a variety of encounters involving employees, passing cars, and moving construction equipment exists, creating risky situations that may result in injury or death. Active approaches, such as the deployment of intrusion detection and alert devices in highway employees and the construction and maintenance of transportation infrastructure, can be effective in reducing these unforeseen situations. The study focus on development of the emergency signal system for the safety of highway workers was carried out to prevent accidents or danger from happening in the straight emergency line on the highway by developing a system of hazard detectors using a distance sensor. Therefore, the development of the Signal Warning Detector (SWAD) for the safety of highway workers was carried out to prevent accidents or danger from happening in the straight emergency line on the highway by developing a system of hazard detectors using a distance sensor. The distance sensor sensed the target at a certain distance and transmitted the signal emitted through the siren device and the emergency lamp mounted on the PLUS Malaysia Berhad (PLUS) car, while the signal was also transmitted to the receiver to create a danger signal to alert the worker by vibrating the vibrator motor located at the worker's hand. The study findings show that commercially accessible technologies have the ability to improve employee health in the work zone by providing early signal warning as vibration. This study adds to the knowledge base by offering methods for the collection and application of intruder sensing technologies for active protection in the work zone. The data produced in the result reveals that by performing the study, it was possible to find the best parameter setting for the Danger Signal Detector system. The farthest distance observed was at 14° of angle, 2.2 meter distance from center, and 1.8 meter sensor height.

Keywords: Arduino, microcontroller, uRAD radar sensor, distance sensor, SWAD

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1. Introduction

Nowadays, the increases of vehicle contribute to the heavy traffic and congestion in highway. This cause any renovation, highway or repair will be conducted during day will lead to delays and congestion at highway. Accidents caused by through traffic at night are more common, serious, and common than accidents caused by construction equipment. [1,2]. The factor that causes night-time construction hazardous are because of visibility problem at night among highways use and highway worker. Besides, the higher percentages of contributing night-time accident are impaired by drugs, fatigue, alcohol, and age-related vision impairments [3].

Highway is very dangerous because it is public road that involve variety of vehicle uses that highway. Accident rates in work zones are greater than equivalent highway sections without work zones [4]. Furthermore, the factor of contributing to cause an accident is the speed limit is 110 km/h which can consider enough to give big impact during accident. If the vehicle approaching the highway zone at the highway, it will be more dangerous for highway worker. An Automation Highway Danger Detector System can detect any danger that approaching danger zone of highway site at the highway. The suitable distance sensor is used to detect the vehicle to give signal to safety system that able to alert the highway worker by using vibration motor as an output. Other major causes included lack of coordination with other nearby projects and miscommunications between the various project participants, congestion and vehicle delays in the working zone, unattended driving behavior, and inadequate capacity traveling work zone [5-8]. According to police yearly road traffic accident records, there are more than ten different forms of road flaws that have resulted in a road accident [9]. One of the road faults that resulted in an accident is a lack of street lighting, particularly at night. Because of the lack of lighting, the motorist cannot see other adjacent modes of transportation well.

Furthermore, this factor causes the driver to use high beam, causing the other driver to feel astigmatism. Light does not come to a single focus on the retina in an astigmatic eye, resulting in blurred vision. Aside from that, one of the worst road highways is the lack of road signs. For example, the old signage was damaged in a car accident, and the road management organisation did not replace it with new signage [10]. This can also lead to an accident owing to a lack of knowledge, particularly for dangerous curves and animal crossing areas. Accidents occur as a result of a lack of information, particularly for dangerous curves.

Cause of that, a programming is created to overcome this issue. The CPU is programmed using the programming unit [2]. The type of terminal utilised is determined by the manufacturer and, in many cases, the customer's request. There is various type of programming unit manufacture by PLC manufacture. The programming unit allows the user to communicate with the circuit of the controller. But the simplest type and easy used is the handheld programmer. A handheld programming device has a connecting cable that able to be plugged into a PLC’s programming port [11]. The advantages of this programming device are compact, inexpensive, and easy to use. Nowadays, many industries prefer to use laptop computer or notebook for programming. This is because it is easy to bring and access at anywhere and anytime. An interface that allows a computer to connect to a PLC's input, and the software application is normally provided by the PLC's manufacturer.

Understanding this section is like providing the equivalents of eyes, ears, and tongue to the brain of a PLC that is a CPU. The I / O section consists of an I / O rack and I / O modules like the figure. Modules of the input interface accept machine or process device signals and convert them into signals that the controller can use. Modules of the output interface convert control signals to external signals used to control the machine or process. Based on book PLC, there are three types of I/O module which is digital, analog, and special [11]. Digital I/O module provide ON/OFF voltage-type signals, and analog modules provide variable voltage or current signals. While the example of special module is High-Speed Control Module, Thumbwheel module, TTL Module and other [12,13]. The PLC's control part is the Central Processing Unit (CPU). Typically, a CPU module is found on one side of the rack assembly. The PLC's brain is the central processing unit. CPU now includes the same microprocessor type that is used on a personal computer. There may be more than one microprocessor in the PLC system CPU. The advantage of multi-processing is that it is possible to separate control and coordination tasks and improve overall running speed. [12]. The CPU's principal function is to read and run computer programmes that are permanently stored in the processor's memory. It interprets the program commands from the memory and acts on those commands [2].

A programmable logic controller (PLC) is a single-processor, computer-based, solid-state device that is a specialized computer used to control and process machines. Programmable logic controllers (PLC) are devices that can manage a variety of industrial equipment and automation systems by simulating the behaviour of an electric ladder diagram [14-16]. A programmable logic controller (PLC) is a microprocessor-based device that stores instructions in programmable memory and perform activities including logic, counting, sequencing, timing, and arithmetic to control machines and processes.

Arduino also able to be used as platform in creating tools or device for education purpose. As an open-source microcontroller, the Arduino can be easily programmed and reprogrammed, and it can be quickly deleted and erased [17-19]. Arduino is a platform that provides scholars and professionals with a low cost and simple way to create devices that communicate with their environment using sensors and actuators. Arduino also capable to be used with other software for details analysis likes LabVIEW and MATLAB. The example of the combination of using Arduino with other software is Virtual Instrumentation (VI) based system used for remote monitoring that develop [20-22]. A system based on Virtual Instrumentation (VI) is used to remotely monitor chosen environmental parameters: humidity, temperature, light intensity, and methane. The educational benefits of this software (learning results) are as follows: development and implementation of the monitoring circuitry, programming or both LabVIEW and Arduino, understanding VI principles and using mob.

There are many applications of Arduino in our daily life. One of the applications is a solar cell 18 automation system based on Arduino Uno with solar input from which AC voltage output can be used to meet the needs of household appliances and office equipment has been successfully implemented [23].

2. Methodology

The purpose of this research is to create a prototype for the construction of an emergency signal system for the safety of highway employees. The Arduino System was employed as the study's medium, and C Programming was used as the language. The Arduino system will be used to control the hardware in the wireless sensor system. C is a high-level, general-purpose programming language that is perfect for creating firmware and portable apps. Dennis Ritchie created C for the Unix Operating System in the early 1970s at Bell Labs, with the intention of building system software. Developing a safety system, creating programming, installing software and hardware, and testing are the methods used in this study. In addition, the purpose of each component in the development of an automated safety system will be thoroughly explained. This study's approach is based on the scope of work and is designed to achieve the research's goal.

The workflow begins by assessing and identifying the safety issue that the maintenance worker is experiencing. Priority is given to the most urgent and significant problem to be handled. The second stage after identifying the problem is to investigate the component that is causing the safety issue to occur and assess how this factor can affect and be related to the problem's result. The decision is determined by differentiating the nature of the factors. The nature type of a factor can be split into two categories: uncontrollable factors and controllable factors. Weather, natural disasters, revolutions, and other uncontrollable factors are examples of uncontrollable factors. Meanwhile, controllable factors include things like safety precaution preparedness, emergency backup, and many more. Following that, if the factor is controlled and can be improved, the method and decision to use the Arduino programmed to fix the problem will be made. However, if the element is uncontrollable, the outcome will be abrupt because nothing can be done to help solve the problem further.

2.1 uRAD Sensor

The Arduino microcontrollers (MCUs) are simply used as a user-to-radar interface, making programming and control easy. With an accuracy of up to 0.04 m or 0.3 percent of the observed range, the uRAD device can recognise up to five different element targets within its field of vision at a range of 0.45m to 100m. It detects speeds from 0 to 75 m/s with an accuracy of 0.05 m/s. The radar also displays the discovered target's signal-to-noise ratio as well as the raw in-phase and quadrature components of the total received signal, allowing the user to access the detected data and do post-processing. Antheral S.L.'s radar and sensing division, uRAD, produces high-performance radar technology for novel applications. RF board interacts with Arduino and Raspberry Pi microcontrollers (MCUs) to turn them into fully functional microwave radar systems is the latest offering. In the ISM frequency band of 24 GHz, the radar has a very low EIRP of less than +20 dBm. Two patch antenna arrays at the field of view portion, one for broadcast and one for receive, create a field of view of 30 x 21 degrees. Other main features also shown in Figure 1.

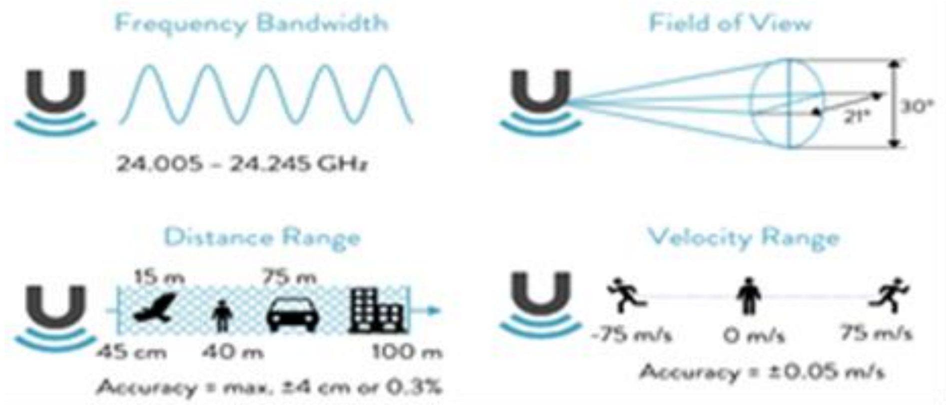
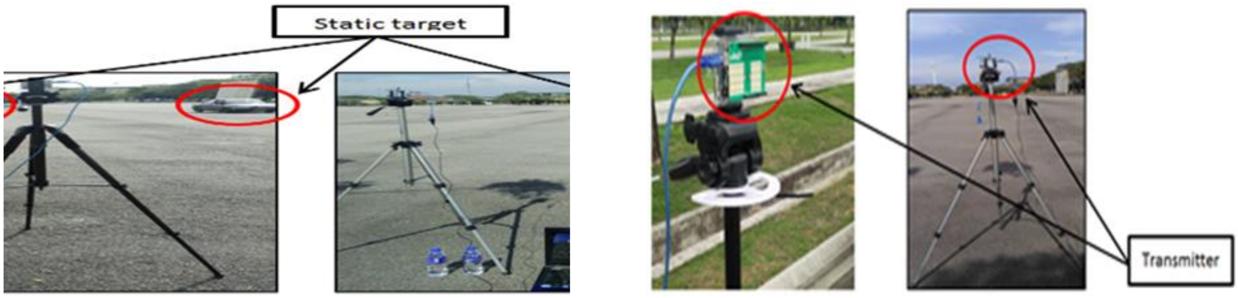


Fig. 1 - uRAD main features

2.2 Sample Testing Preparation

Figure 2(a) shows the setup of the programming and the device for the experiment that being conduct. The experiment is conducted with static targets at different distance from the transmitter to test whether the transmitter device is function or not. This experiment very important to receive feedback data before testing in real situation in highway. Figure 2(b) shows the setup for the transmitter device during the experiment that being conducted. The experiment is conducted with different distance from the transmitter to test whether the transmitter device is function or not.



(a) (b)

Fig. 2 - (a) Device setup experiment; (b) Transmitter prototype

Table 1 - Table testing for Response Speed Test

Signal Warning Detector (SWAD) speed responses test	
Date	19/7/2021
Type of vehicle	van
Situation Wheater	Day/wet
Speed limit	110km/h

No of testing	Detection distance (m)						Reaction time (S)
	50	60	70	80	90	100	
1				/			3.54
2				/			3.50
3					/		3.25
4				/			2.90
5					/		3.21
6					/		3.49
7				/			3.45
8				/			3.33
9					/		3.40
10					/		3.14
11			/				2.75
12					/		3.45
13					/		3.21
14				/			3.26
15				/			3.45
16				/			3.16
17					/		3.18
18				/			3.42
19					/		3.26
20					/		3.41

2.3 Testing in Real Situation

The second stage of the experiment have been conducted as real situation with PLUS workers at the emergency lane highway. Figure 3(a) shown the installation of receiver at the worker ‘s arm and vibrator motor at the worker’s wrist. Installation of a bracket containing an emergency lighting, a power supply, and a siren on the PLUS vehicle is depicted in Figure 3(b). Figure 4 show the real situation has been conducted with PLUS workers at highway emergency lane during the day situation. In various situations as rainy night, rainy day and sunny day the tests were also undertaken.

(a) (b)

Fig. 3 - (a) Receiver and vibrator motor position; (b) Transmitter position

Fig. 4 - Real situation of testing

3. Result

The emergency signal system prototype is being utilised to develop a distance sensor-based danger detecting system. This system's purpose is to alert and protect workers who are working in an emergency straight line on the roadway. This system is an automation programming for the safety system in a straight line, which will alert the worker to any potential hazard from behind. Radar is a gadget that detects objects within its range of action. It works by sending out an electromagnetic wave into the atmosphere. The target reflects this wave, which returns to the radar. The type of radar is determined by the shape of the going and arriving waves, as well as the radar design. The emergency signal system prototype is being utilised to develop a distance sensor-based danger detecting system. This system's purpose is to alert and protect workers who are working in an emergency straight line on the roadway. This system is an automation programming for the safety system in a straight line, which will alert the worker to any potential hazard from behind. Radar is a gadget that detects objects within its range of action. It works by sending out an electromagnetic wave into the atmosphere. The target reflects this wave, which returns to the radar. The type of radar is determined by the shape of the going and arriving waves, as well as the radar design by installation of SWAD.

3.1 Parameter 1: Distance from Reference

Based on data from Table 2 the experiment that adjusts the parameter of distance from center point (X) at Left Lane and Emergency Lane, the maximum value of distance could be discovered by observing the data from the first experiment using a line graph.

3.2 Parameter 2: Angle of uRAD

Table 3 shows the data collection of maximum distance detected at both emergency and left lane that the parameter of angle is varies.

4. Conclusions

The creation of a Danger Signal Detector System capable of addressing the issue that has arisen among highway workers on the roadway. The project's goal was also met when it was able to construct an Automation Highway Danger Detector System. The second goal is to be able to discover and optimise parameter settings for the Automation Highway Danger Detector System. These two objectives demonstrate that the project's development can resolve the issue that contributes to a rise in the accident rate among highway workers. Workers' psyche will improve because of this initiative since they will feel more confident in their ability to accomplish their job. Another impact was that the level of safety for the user and worker will be at its highest because this project may provide an early warning of any dangers that may befall them. Several technologies and software were employed in this project. There is also the use of Arduino that is integrated with an uRAD sensor that functions as a distance sensor to detect the presence of a vehicle for safety purposes. To boost the level of safety for this project, a combination of different devices such as an emergency siren, a beacon lamp, and a vibrator was used.

Table 2 - Table testing of distance from reference for Response Speed Test

Distance from Reference (m)	Max. Distance at Left Lane (m)	Max. Distance at Emergency Lane (m)
1.0	55	55
1.2	55	55
1.4	45	55
1.6	45	55
1.8	40	55
2.0	40	55
2.2	40	55
2.4	35	55
2.6	35	55
2.8	30	50
3.0	25	45
3.2	35	35
3.4	35	50
3.6	35	50
3.8	30	40
4.0	35	35

Table 3 - Table testing of angle of uRAD (°) for Response Speed Test

Angle of uRAD (°)	Max. Distance at Left Lane (m)	Max. Distance at Emergency Lane (m)
0	45	55
2	40	55
4	45	55
6	35	55
8	35	55
10	30	55
12	25	35
14	0	30
16	0	25
18	0	20

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