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IoT-Based Alert Notification for Tilted Road Sign Boards with Solar Energy

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ABSTRACT

Currently, the department of Jabatan Kerja Raya (JKR) in Malaysia depends on the notification from public's complaints or on-site spot checks when there are tilted road sign boards. This has caused delays in repairs and could put public safety in jeaopardy. In this paper, an IoT-based alert notification for tilted road sign boards using solar energy is proposed. A Rapid Application Development methodology (RAD) is used to produce a working prototype of the proposed system with NodeMCU ESP8266 microcontroller and Arduino IDE. The results of our implementation show that we are able to detect tilted sign boards and send email alert notifications to the responsible parties accordingly.

Keywords: IoT, solar energy, road sign, alert notification

INTRODUCTION

Internet of Things (IoT) is a worldwide system of "smart devices" that can sense and connect with its surroundings and interact with users and other systems (Dhingra, Madda, Gandomi, Patan, & Daneshmand, 2019). IoTs are used as the medium to communicate with humans and non-living objects using sensors to navigate, sense and collect data before loading to the cloud storage. Building a smart city by incorporating IoT devices with common infrastructure is one of the popular domains amongst other applications of IoT.

One component in the construction of a smart city that we can consider is the general traffic condition. As such, traffic road sign boards are important to convey the road conditions to the user or the commuters. This is because road sign boards ensure public welfare against accidents or unexpected incidents. The Malaysian government has come out with a few approaches to provide information and communications technology (ICT) platforms such as the Aduan Jalan Kementerian Kerja Raya (KKR) mobile application (Kementerian Kerja Raya, 2019), email, SMS and hotline call to receive road sign board damage complaints from the public. Nonetheless, these solutions could not help much because the road users do not cooperate accordingly (Samsir, 2019).

The current manual method of inspecting road sign boards requires staff patrolling by the Jabatan Kerja Raya (JKR) as a daily routine. The team will travel slowly by vehicle to inspect the road sign boards one by one, sometimes, up to a distance of 290 kilometers. If the staff found any defected road sign board, they will jot down the information such as the location and damage type into a log book. Sometimes, they do not even notice the damaged road sign board through naked eye inspection. Even worse, road sign boards may be stolen by irresponsible people. This can lead to a low possibility for the road sign board to be repaired and may be one of the factors contributing to road accidents. Consequently, the problem encountered by the JKR department in Malaysia is that they are unable to receive real-time notification when a road sign is damaged.

Accordingly, the objective of this project is to design and develop an IoT-based alert notification to the relevant authorities through email for tilted road sign board using solar energy. The source of electricity to power up the system is by using solar panels to reduce operational costs.

RELATED WORK

In this section, three existing systems will be examined namely Konnect: An Internet of Things (IoT) based Smart Helmet for Accident Detection Notification, Smart Safety Helmet, and Wireless Monitoring Zigbee Solar Street Light Controller. By studying and reviewing the current systems, we can identify their limitations.

A group of researchers at the Sri Sivasubramaniya Nadar College of Engineering, India has introduced the accident detection and notification helmet as an approach to improve the safety of motorcycle riders (Chandran, Chandrasekar, & Elizabeth, 2016). According to the authors, many death cases were caused by delays in accident notifications. They built a system called Konnect: An Internet of Things (IoT) based Smart Helmet for Accident Detection Notification. This system is equipped with a set of sensors and Global Positioning System (GPS) embedded on a helmet. The sensor used is a tri-axial accelerometer that calculates the change of acceleration of the helmet wearer's head tilt direction in the x, y and z-axis. The system detects that a crash has happened if the average of the acceleration threshold is overreached. the built-in accident notification system sends the information through cloud access. Figure 1 shows their notification message.

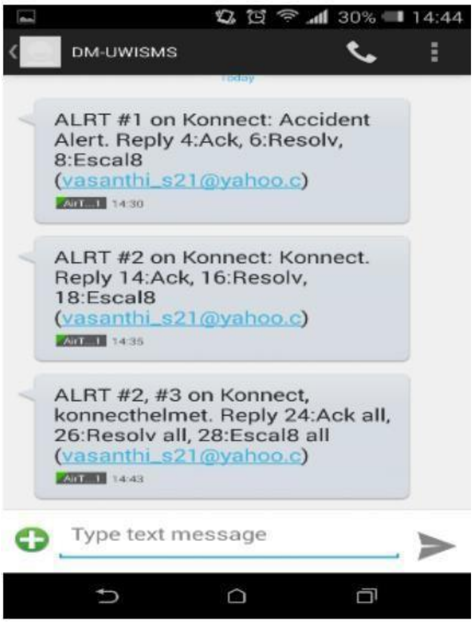

Figure 1: Text message received by the motorcycle rider

TM R&D (Telekom Malaysia Research & Design) proposed a helmet that is digitally connected called Smart Safety Helmet to improve the safety of their workers at the construction site (Lim, 2019). The smart safety helmet uses LTE (Long-Term Evolution), Wi-Fi and Bluetooth connections. It is activated by various connections depending on the event connectivity condition. Figure 2 shows the monitoring web-based system used in the Smart Safety Helmet. This system is a wireless monitoring system and the sensors provide data to the cloud to be shared with the supervisors and other teams at the construction site. Supervisors are allowed to view data such as attendance, and status of safety helmet wearers in case they took off the safety helmet during working hours, by logging-in to the web-based system that is viewed in real-time.

Figure 2: Monitoring web-based system used on the Smart Safety Helmet

Wireless Monitoring Zigbee Solar Street Light Controller (Jinsdon, 2020) is a street lamp system using solar energy as the source of its power, invented by Shenzhen Jinsdon Lighting Technology Co. located in Shenzhen Longhua, China. This system is embedded with infrared sensors and Zigbee antenna to measure the distance of other street lamp nodes to send and receive data simultaneously from the GPRS (General Packet Radio Service) concentrator. The purpose of this feature is to allow remote monitoring of street lamps by personal desktop or mobile application (Professional 10 years in Smart Street Lights, 2020).

Based on this review, our proposed system consists of most of the criteria and features that can detect damaged road signs and notify the authorities accordingly. For the time being, monitoring features, web-based system applications, and Zigbee connectivity are not applied to the proposed system to reduce the system design complexity. The advantage of our system is the simple design and self-generated power using the renewable solar energy.

METHODS & TOOLS

The system requirements phase is considered the first phase of RAD to identify the target users, hardware and software requirements. The requirement analysis was conducted by interviewing a JKR engineer in Pontian, Johor. Since this project is expected to be completed in five months, we have chosen the Rapid Application Methodology (RAD) development cycle (Chien, 2020) as it allows various changes in any of its development phases.

1. **Requirement System Analysis and Design**. An interview session was set up with Encik Zulkiflee Bin Samsir (see Reference). He is an assistant engineer in the road safety department of Jabatan Kerja Raya in Pontian district, Johor. He has been in the department for about thirty years. The interview session is done through a telephone call. He acknowledged that the proposed system will be a good system to reduce the road accident rate.

2. **Hardware Requirement**. The hardware requirement will list out all the hardware used in developing this proposed system namely microcontroller, sensors, solar panel and others. An email account and a desktop/laptop are also needed to receive notifications. Table 1 shows the electronic devices and sensors used in developing this proposed system.

Table 1. Electronic devices and sensor used in the proposed system.

Tools	Description
NodeMCU ESP8266 microcontroller	It is a system-on-chip that can be programmed by using Arduino IDE software downloaded into the personal computer. It is designed with built-in networking capability. Other than that, it receives input from the sensors and sends it to the cloud.
Tilt sensors	Tilt sensor module. Input component that detects the orientation or inclination of the road sign board. It uses mercury liquid to calculate the angle by touching the 'on' and 'off' positions.
Solar panel	A device used to obtain energy from sunlight and convert it into electricity.
Battery 12V	Store and provide power to the microcontroller.
Lithium Battery Charger Module	Connected with the solar panel to provide power to the battery and monitor the operate-ability of battery capacity. Plus, it has battery protection that functions to control the current voltage, overcharge and short circuit protection.
Jumper wires	Has connector pins at each end, connecting two points to each other without soldering. Jumper wires are typically used with breadboards. It has three types namely male-to-male, male-to-female and female-to-female. The proposed system uses all types of jumper wires.

3. **Software Requirement**. The software required for this proposed system is Arduino IDE (Arduino, 2020). It is a platform application to write and compile codes in IoT Arduino projects. It is an opensource software that can be downloaded into Windows, Mac OS and Linux. This software provides C/C++ language.

Figure 3 shows the proposed system design. Due to the limitation of our resources, we do not consider GPS and GMS in our design. NodeMCU ESP8266 acts as the microcontroller to perform the task and execute the application. It is also the processor of the system. Tilt sensor connected to it is the input component. The microcontroller board needs a power supply to be fully functioning. The solar power stored in the lithium battery then provides the power to the microcontroller board. The reason for choosing solar energy is that it is the cleanest power source that will not release any harmful gas emissions while we extract electric energy from the solar panels.

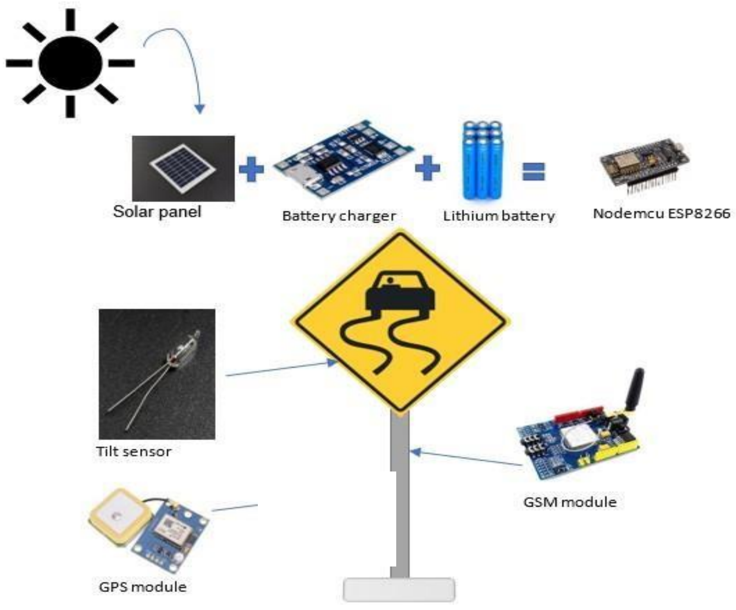

Figure 3: System layout and design.

Figure 4 describes the proposed system's general architecture which is divided into three parts. The three parts are hardware/sensors, cloud and alert notifications received by users. The sensors will read the data and send it using WiFi to the cloud. The cloud is the medium of communication between the hardware and users. The measurements and data are received by the users through alert notifications on the smart phone and email.

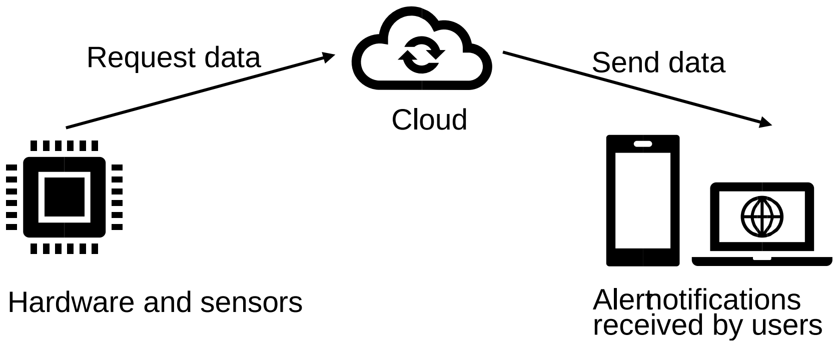

Figure 4: Proposed system architecture

TESTING & RESULTS

In this phase, we test our prototype to ensure it fulfil the objectives of this project. We conducted the component testing and full circuit testing.

1. Component testing – Components such as solar panel, solar battery charger, battery, Nodemcu ESP8266, tilt sensor, and GPS sensor are tested by connecting to the power source. Then the components are tested by compiling the codes from Arduino IDE. Nodemcu ESP8566 will show blue LED light when it is connected to the power source. Figure 5 shows it is working successfully.

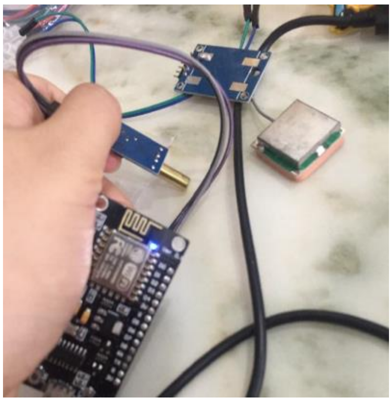

Figure 5: Nodemcu ESP8266 testing

2. Full Circuit Testing – It is done to make sure the functions of the system are working correctly. All the components must be linked and functional. Tables 2 and 3 show the testing conducted.

Table 2. Test on software requirement for the proposed system.

Test Case Name	Nodemcu ESP8266		
Test Case Description	To assess whether the Arduino IDE platform functioned properly and to ascertain the Nodemcu ESP8266 working properly.		
Pre-Condition	Nodemcu ESP8266 needs to be connected to the power source. Set up Arduino IDE platform in the laptop for programming purposes.		
Steps	Test Description	Expected Result	Result
1	Supply power to Nodemcu SP8266 using solar energy.	The blue light at Nodemcu will light up.	Pass
2	Execute Arduino IDE to set up the Nodemcu ESP8266.	The display shows Arduino IDE can be run.	Pass

Table 3. Sample test case for the tilt sensor.

Test Case Name	Tilt Sensor		
Test Case Description	To check the tilt sensor working correctly and to ensure the tilt sensor turns on LED when it is tilted.		
Pre-condition	The tilt sensor is connected to Nodemcu ESP8266 using female-to-female jumper wires.		
Steps	Test Description	Expected Result	Result
1	Connect the tilt sensor to Nodemcu ESP8266.	The tilt sensor is will light up.	Pass
2	Decline the tilt sensor about 45 degree.	The LED will light up and turned off when it is set to be straight.	Pass

LIMITATIONS & DISCUSSION

There are a few limitations in this prototype system. Firstly, a good internet connection is required to send and receive the alert notification because it is the medium for data transmission used in this IoT project. Thus, the road sign board must be located in a smart city that has wireless internet connection.

Second, the weather condition has a huge impact on connectivity. Under conditions of constant rain up to seven days, there may not be sufficient sunlight for the solar power system. However, the solar circuit can be charged with an incandescent bulb. Therefore, this needs regular maintenance to keep an optimum energy level for the proposed system.

Furthermore, the design of the proposed system lack convenient data transmission. However, the proposed system design can be improved to increase its functionality. For example, the SMS feature can be added so that alert notifications can be sent to the authorities. In addition, GSM technology is used to send SMS because the technology can be implemented in a rural area with poor internet signals. Other than that, radio wave data transmission can be considered to replace internet transmission. Next, the location detection can be added in the future using GPS sensor or GPS locater to provide much more precise information.

FUTURE WORK & CONCLUSION

There are some functionalities of the proposed system that can be improved. For example, the short message service (SMS) feature can be added for alert notifications. The location detection feature can be added using the GPS sensor or GPS locater to provide precise information.

The current proposed prototype with road sign board attached with a tilt sensor can read the inclination of the sign pole. Our prototype is designed to be smart where it can send a real-time alert notification through email to the receiver (relevant authorities) when road sign board inclinations are detected. Therefore, the objective for this proposed system is attained.

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