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DEVELOPMENT OF A PORTABLE SOLAR-POWERED TRAFFIC LIGHT CONTROL SYSTEM FOR A REMOTE SINGLE LANE BRIDGE

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ABSTRACT

The uncertainties of terrain in some rural area in Malaysia make the building of a bridge a real challenge. When the construction of a bridge is built over railways, space is a matter of concern. This paper proposed a stand-alone traffic light solution for the drivers and motorist in Kampung Batang Benar, Negeri Sembilan who need to cross the railways via a single lane bridge. The single lane bridge can only accommodate one vehicle at one time and motorists have to wait for their turn to cross to the other end. Having a single lane bridge with no traffic light to control the traffic definitely contributes to congestion. On a peak hour, cars and motorcycles start to queue and there is no ruling on which end should go first. It will be a costly and not reliable approach to station traffic controller personnel at such a place. This project develops a portable stand-alone traffic light which uses Arduino microcontroller and Xbee wireless communication system. Since the system is using a wireless communication and portable, its usage can be extended to any remote road in the rural area to assist the traffic flow. The system is also equipped with solar photovoltaic and a battery bank to ensure the operation is continuous even during the night. The implementation of this system is perceived to put the traffic under control with minimal assistance from human operator.

Keywords: control system, remote traffic light, microcontroller, wireless communication.

INTRODUCTION

Stand-alone traffic light which is also known as solar-powered traffic light, is a signaling device positioned at road intersections, pedestrian crossings, or other remote locations in order to control the traffic. Kampung Batang Benar, a small rural area in Negeri Sembilan has a stretch of railways for the commuter train owned by Keretapi Tanah Melayu. These railways divide the town into two and limit the mobility of the motorists. A bridge was designed to connect the areas affected and due to the space and land constraints, it was built with a single lane. Figure-1 shows the geographical location of the town and the stretch of the commuter railways.

Figure-1. Location of single-lane bridge at Kampung Batang Benar, Negeri Sembilan.

Figure-2 and Figure-3 depict the problems occur at the single lane bridge. The incoming and outgoing ends of the bridge are two-lane roads and therefore making the incoming point of the bridge a bottle neck to the traffic.

The solar-powered traffic light, which is also portable, is proposed to solve the problem faced by the motorists. There are several advantages of employing the solar-powered traffic light in this kind of terrain or area compared to the conventional traffic light. The solar-powered traffic light module is easy to be installed and to be dismantled. The solar-powered traffic light does not require a pole instead it can be hung on cables. The system does not depend on the main grid power supply because it has the solar module to power the traffic light and its components. The battery bank is equipped in the system so that the power is always up even at night. This system also employs the wireless communication system which be placed on the traffic light and requires a simple cabling on the casing of the traffic light as mentioned in [1-4].

Figure-2. The two-lane incoming and outgoing roads.

Figure-3. The construction of the single lane bridge.

In brief, there will be one traffic light with a control system board embedded onto it to be placed at each end of the bridge as discussed in this introduction section. The control board consists of an Arduino microcontroller, Xbee wireless device for communication purposes and infra-red sensor. The concept of the design is discussed in the methodology section. The prototype is built, tested and selected results are presented in the results and discussion section.

METHODOLOGY

This section focuses on the design of the system and the development of the system prototype was done in stages. The first stage towards the realization of the prototype was to work out the control design system which includes the programming of the Arduino microcontroller. The developed control system was simulated and verified so that the controller produces correct output signals. The next stage is to translate the simulated circuit diagram and programming into hardware prototyping. The finished prototype was tested and again at this stage the output signals were verified according to the possible scenarios that could occur.

Software development

As mentioned in the introduction, the traffic light is installed at each end of the bridge and a control board is embedded onto it. The whole system is powered by the solar photovoltaic and having a battery bank as a back-up power source. Figure-4 demonstrates the flow of the system. During the day, the solar panel will power the traffic light and the excess power harvested is used to charge the battery. The motion sensors will sense the presence of the vehicles and transmit the signal to the Arduino control board before the outputs are displayed [5].

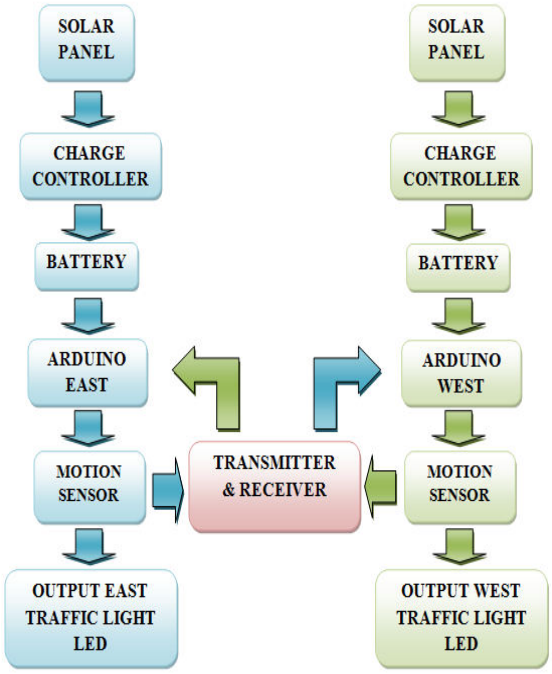

Figure-4. The block diagram describing the proposed system.

There are 3 conditions or scenarios for the controller to consider when transmitting the output signal and those are:
Condition 1 : There are no vehicles presence at both ends of the bridge.
Condition 2 : There are vehicles presence at BOTH ends of the bridge.
Condition 3 : There are vehicles presence at ONLY one of the bridge ends.

Control system development

There are four main components used in the control system, namely:
i. Arduino Microcontroller: Obtains the input signal, processes and produces the output singnals.
ii. Arduino Shield: extends the usage of Arduino microcontroller and acts as an interface for XBee radio communication.
iii. Xbee: A wireless radio communication that is used to transmit and receive the signal from the infrared sensors.
iv. InfraRed Sensor: Senses the motion and presence of the vehicles at the bridge ends.

The control decision was written by using C-programming, compiled by Arduino IDE compiler and then uploaded onto Arduino microcontroller. The Xbee radio communication on the other hand is programmed by using CoolTerm and X-CTU software. In this system, the devices are set to be used as transmitters and receivers so that data from the sensors can be conveyed to the Arduino microcontroller as mentioned in [4] and [6].

The rulings of the traffic light are as follows:
(i) Initially both traffic lights (east and west) are set to red.

(ii) If vehicles are present at both ends, the traffic lights remain red for few second then the east end will turn green. This project gives the east end the priority.
(iii) The traffic light will be green for 1000 seconds before turning yellow and then red.
(iv) The west end traffic light will turn green letting the vehicles to move.
(v) If there are no vehicles (i.e all vehicles have crossed the bridge) then both traffic lights will turn red.

Hardware prototype

Figure-5 shows the schematic diagram of the system. The control board consists of the Arduino microcontroller, the interfacing device and the wireless communication device. The main control board is powered by the solar panel during the day and battery bank during the night. The infrared sensors produce signals and transmitted to the microcontroller. The L.E.Ds represent the traffic light's bulbs.

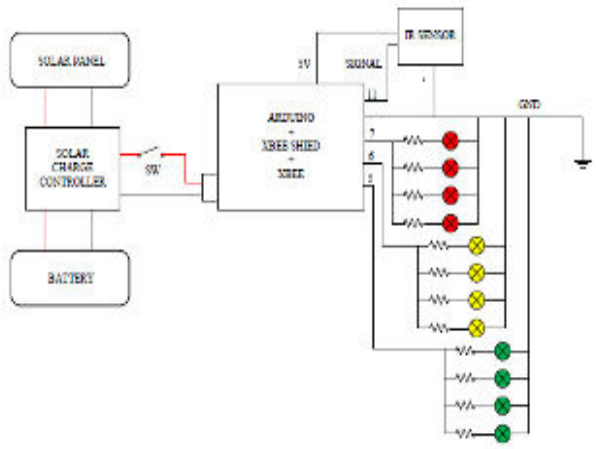

Figure-5. The finalized schematic diagram of the system.

Figure-6 shows the finished prototype and ready to be implemented.

Figure-6. The finished prototype and its connections.

Table-1 tabulates the list of the components used and the costs.

Table-1. List of the components used and the costs.

Component	Unit	Price/ Unit	Price
Arduino Uno	2	85.00	170.00
XBEE	2	140.00	280.00
IR Sensor	2	35.00	70.00
XBEE Shield	2	80.00	160.00
Supply Connector	2	3.50	7.00
XBEE USB Adapter	2	150.00	300.00
Battery Connector	4	0.40	1.60
Battery	2	35.00	70.00
Solar Charger	2	120.00	240.00
Solar Panel	4	25.00	100.00
L.E.Ds	24	0.30	7.20
Resistors	24	0.05	1.20
Toggle Switch	3	1.60	4.80
Boxes (Large)	2	11.50	23.00
Boxes (Small)	2	2.00	4.00
Heat Shrink Tube	1	1.20	1.20
Cable	4	1.00	4.00
Circuit Board	2	3.50	7.00
TOTAL			**1451.00**

RESULTS AND DISCUSSIONS

A simple series of tests according to the conditions were done to ensure the programmed microcontroller, the wireless communication devices and the sensors are working in order. The L.E.Ds represents the traffic lights and two small boxes represent the vehicles. The testing is limited to only three conditions as mentioned in the introduction section. Figure-7 shows condition 1 of the testing when there is no vehicles presence at both ends of the bridge. Both traffic lights will turn on the red lights. By doing this, if there are incoming vehicles from both end of the bridge, the drivers need to stop first and this will ensure the safety of the traffic.

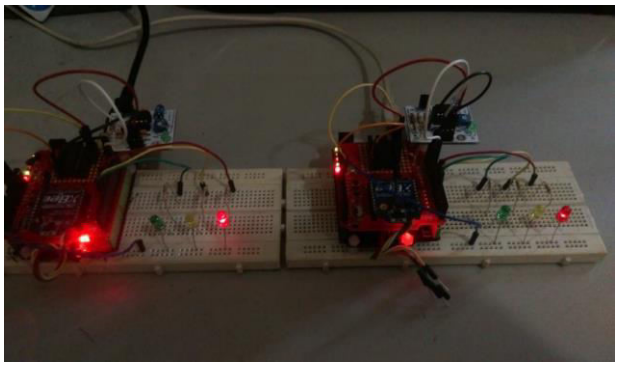

Figure-7. Two red L.E.Ds are on when there is no presence of vehicle at both ends of the bridge.

Once the vehicles are within the sensor range, a signal is transmitted to the control board through the wireless communication devices. The programmed Arduino controller will transmit the output signal based on the rule sets. Figure-8 illustrates there are vehicles presence on both side of the bridge. One of the traffic lights must turn green and the other one remains red. In this project, the east end will have the priority by considering the traffic volume coming from that side.

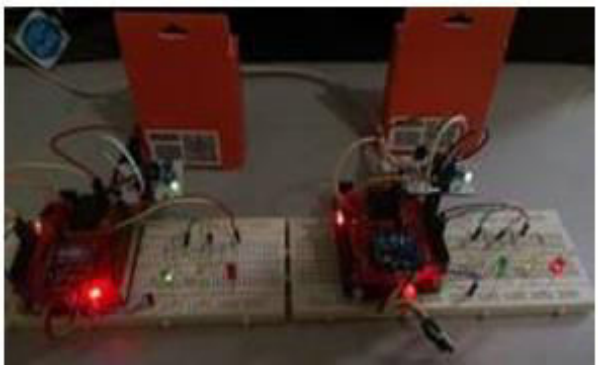

Figure-8. One of the L.E.D turns green and the other end remains red.

Assuming the vehicles are all cleared at the east end, the sensor will transmit a signal informing the controller there is no vehicle presence. Thus, the other traffic light will turn green allowing the vehicles to pass through the bridge.

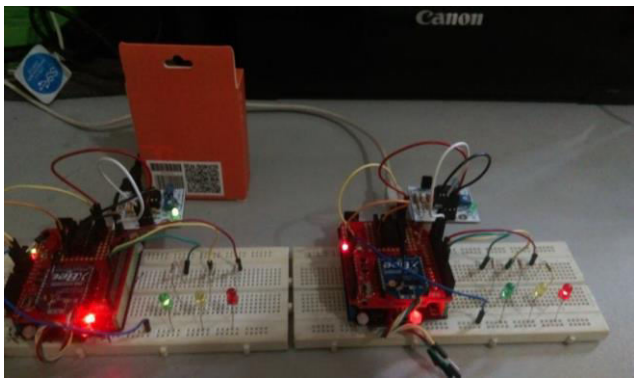

Figure-9. One of the L.E.D turns green and the other end remains red.

CONCLUSIONS

A simple prototype of a stand-alone traffic light system powered by the solar photovoltaics has been successfully developed and tested. Three straightforward scenarios or testing conditions were chosen and the programmed microcontroller was able to produce correct output signals for each scenario. The portability feature of this system makes it very practical to be installed at places where traffic lights with poles are not suitable to be set up. The implementation of this proposed system will solve the traffic congestion and uncertainties at the mentioned location.

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