Energy-Efficient and Emergency Dispatch System for Smart Street Lighting

Puppala Rajendhar, J. Belwin Edward, and I. Jacob Raglend

Abstract Smart cities are going to be the need for the future generation. For any city to be smart, two major things to look at are its energy consumption and the safety of citizens. The aim of this work is to optimize energy consumption in public lighting and to make roads safer by ensuring quick dispatch of emergency services upon detection of an accident or any abnormal condition on the roads. Public lighting has a huge energy consumption. For public lighting energy optimization, the proposed system uses a microwave Doppler motion sensor interfaced with Arduino to detect vehicle movement and switch on corresponding lights to illuminate the road, hence saving a lot of energy against traditional street lights that are kept on for the entire duration of the night. A number of lives are lost annually in road accidents due to emergency services reaching a few minutes later than needed. To tackle this issue, the proposed system demonstrates a prototype model to detect an accident, or any abnormal condition such as a roadblock and inform the nearby authorities to take necessary action. The novelty of this system is that it is placed on roads rather than vehicles which makes it independent of vehicle type and is accessible and affordable to all.

Keywords Energy efficiency · Emergency dispatch system · Smart street lighting · Sensors

1 Introduction

This work is aimed to be incorporated into smart cities that are designed to be energy efficient and secure. Both the systems are conditioned to be suitable for accident prone roads where any kind of abnormality can lead to accidents and casualties.

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1.1 Objective

Hence, the objective of this work is split as:

Efficient Lighting The system incorporates a Doppler-based sensor to detect movement and light the street lamps. The sensor is more durable and efficient compared to its popular alternatives. The aim of this system is to make the energy of the street efficient in the wake of the energy crisis in the world. The novelty of the system lies in the motion detection-based technology which responds the same for cars as well as pedestrians and animals, hence increasing the visibility for incoming traffic and reducing potential accidents.

Safety Dispatch System The system addresses the issue of accident prone roads being poorly monitored, by reducing the amount of time it takes to report an accident. The system uses laser beams to detect vehicle accident and instantly reports the accident location to the emergency response services. The system can also detect heavy traffic blockages and inform the relevant authorities for this condition so that an appropriate response team can be dispatched.

1.2 Motivation

With the rise in technology, the need to build smart cities has become imminent. Energy-efficient and secure roads can be considered to be the building blocks of such a model. The use of smart street lighting although being carried out requires major infrastructural changes thus is both costly and time consuming. The incorporation of a microcontroller-based Doppler radar sensor saves such costs as it can be directly incorporated into the existing lighting systems and prove energy efficient and a better alternative to conventional sensors and lighting systems.

Traffic accidents occur on a regular basis. While these accidents are sometimes unavoidable, the major reason for increased fatalities in serious road accidents is due to the long response time required by emergency services to reach the accident location. The project proposes a system, which can be implemented for highways and danger prone zones, where abnormal conditions such as heavy traffic, accidents, and cattle can be fatal. The novelty of the system lies in the fact that it can be implemented on roads instead of individual vehicles, thus being accessible to all, making it the first of its kind.

1.3 Background

Energy-Efficient Lighting The problem statement of the system is basically energy-efficient lighting of streets. The problems which are encountered generally are

cost, infrastructure changes, sensors, etc. There have been various such models and systems developed by researchers across the globe. A rigorous field study shows that there have been various algorithms and systems which have been developed for implementing the system.

There are elicited algorithms [1] where the authors use ZigBee-based wireless devices to handle street lamp systems more effectively thanks to an integrated interface and control design and a sensor combination to ensure the desired system parameters [2]. Authors proposed a novel street lighting design for energy management based on traffic flow (LED). In response to adaptive traffic on the road, the built smart grid-based system uses a low-power ZigBee mesh network to provide maximum energy efficiency. The flexible wireless network of smart LED lights provides improved reliability, lower costs, and greater customer satisfaction [3, 4]. Energy-efficient smart street light system is prepared based on daylight and night power by analyzing the object's image and sending a control message to the street light block [5]. Smart street light system using Arduino Uno used sensors such as light dependent resistor (LDR) to indicate day/night time and photoelectric sensors to detect street motion. The Arduino Uno was used as a brain to monitor the system of a street light [6]. An energy-efficient pedestrian-conscious smart street lighting system is built; each pedestrian is identified via his/her smartphone, sending position and configuration information to the SSL server periodically. Each lamp is equipped with a Zigbee-based radio system for street lamp control and receives control information from the SSL server via multi-hop routing [7–9]. A smart framework is proposed for the control of wireless-based public lighting networks and the DALI protocol. The DALI protocol uses bidirectional communication with the ballast to control and track its status at all times.

The research clearly elicits modern techniques that have been used to achieve energy-efficient lighting. The system hardware developed in the project was implemented to be different yet at par with the above-mentioned systems and complex algorithm and thus proposes a new sensor to control and manage to light.

Safety Dispatch System for Roads The problem statement of the system is to dispatch emergency services in case of abnormal conditions on accident prone roads and highways. The definition of 'abnormal conditions' is defined as the occurrence of a minor or fatal accident or the blockage of the road due to excessive traffic or vehicle breakdown, for the purpose of the project but its scope is not limited to it. On the basis of the literature, a survey performed and it was concluded that the existing research is intensively oriented toward systems that are built on vehicles and sometimes even drivers. The algorithms and systems are elicited.

Amin et al. [10] designed an accident location detection system using GPS and reporting using GSM for locating the exact position of a collisioned vehicle using GPS and sending collision information to the prescribed numbers using the GSM module using a bump sensor mounted on the vehicle [11]. Algorithms for road safety based on GPS and communications systems WAVE developed via WAVE communication, V2X, which alerts the driver to the risk of accidents, implementing

algorithms using data received from a GPS system. Highlighting three scenarios: crossing or intersection; abrupt approach to the vehicle ahead; and multi-algorithm path curves [12]. The accelerometer-based transport system is designed and implemented to detect abrupt changes in the vehicle's g-forces due to accidents. When the g-force range is compromised by the incident, the microcontroller triggers the GSM modem to send a prestored SMS to a predefined phone number [13]. Piezoelectric polymer-based sensor for robotic applications for collision detection is proposed and has a high dynamic range for touch sensation and robust adaptability to detect collisions on complex surfaces. The architecture enables human and robotic cohabitation in cooperative environments requiring sophisticated and reliable collision detection systems [14]. A new safety indicator based on trajectory analysis is proposed. By trajectory, they meant a time function that describes vehicle movement in both horizontal (longitudinal and transverse) directions including not only its track on the road but also speeds and accelerations. Those trajectories define interactions between the vehicle/infrastructure/driver and expose insufficiencies that can lead to accidents. Such trajectories are measured using two roadside observation systems that evaluate the trajectories of vehicles at two specific locations: curves and crossings on rural roads.

The system proposed and demonstrated in this article is built upon the works of such literature and hence develops a new framework to be incorporated into roads as an alternative and to reduce the cost while increasing the accessibility.

The article is organized in Sections. Section 1 is the introduction of the article comprises objectives, motivation, and background for the proposed work, followed by Sect. 2 which covers the technical specifications of the components used. It also deals with design approach and details such as circuit diagram, schematic diagram, and flowchart for the proposed system. Section 3 demonstrates the prototype design and results of the proposed system. It is followed by a conclusion in Sect. 4.

2 Description of the Proposed Methodology

2.1 Smart Street Lighting

To control the switching of street lights so as to reduce energy consumption and improve the efficiency of a street lighting system, the system is meant to identify vehicle or pedestrian movement and accordingly switch on a set of street lights to provide appropriately lit street and consequently switch off the light upon no vehicle or pedestrian detection. The incoming vehicle should trigger a sensor that lights up the LEDs and provides efficient street lighting. The system is controlled by Arduino.

Sensor HB100 The HB100 Doppler-based sensor detects motion and velocity of the oncoming vehicle and sends a high output to the microcontroller which in turn turns on the sequence of LED lamps. The sensor can be placed inside a box and is comparatively weather resistant and suitable for all kinds of climate. This increases

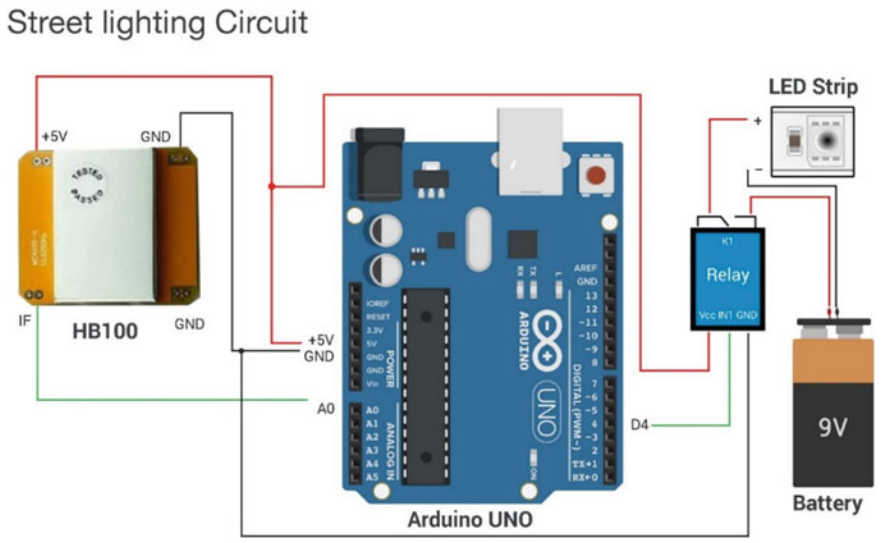

Fig. 1 Circuit diagram for street lighting circuit

the efficiency of the system and saves energy and maintenance costs. The essential features incorporated in the sensor are its low current consumption and long detection range. The sensor has to be connected to the amplifying circuit, whose parameters can be adjusted to get the desired range of detection of movement (Figs. 1 and 2).

The above schematic highlights the proposed design of an efficient street lighting system. The incoming vehicle will be detected by the HB100 microwave motion sensor connected to the Arduino Uno and upon detection will light up three consecutive light for a specified duration and will respond the same for every vehicle that arrives subsequently (Fig. 3).

The flowchart illustrates the software algorithm for the proposed system. The system code runs on Arduino IDE framework.

2.2 Emergency Dispatch System

This system essentially aims at the quick dispatch of emergency services upon detecting abnormal activity on accident prone roads and highways. In the scope of the project, the abnormal road conditions are defined as traffic blocks and accidents but are not limited to it. The system essentially is a large-scale implementation of trip wire with added features. If abnormal conditions as defined were to occur on the road, it would lead to a trip wire of laser being cut for more than a set time and a message alert containing the location of the incident will be sent to the authorities.

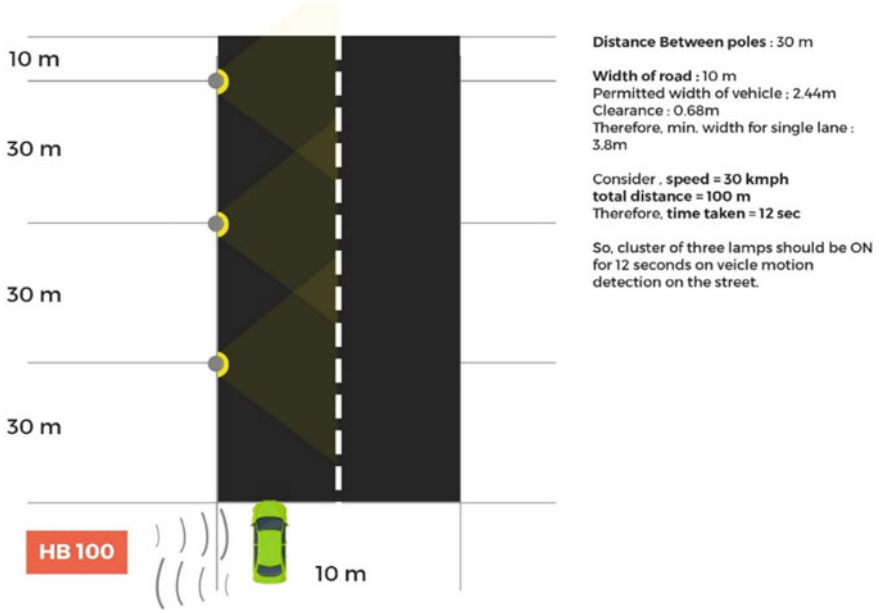

Fig. 2 Schematic of the design of efficient street lighting

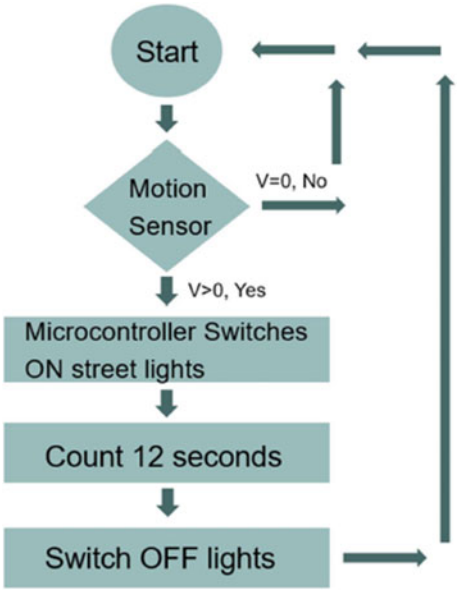

Fig. 3 Proposed flowchart for smart street lighting system

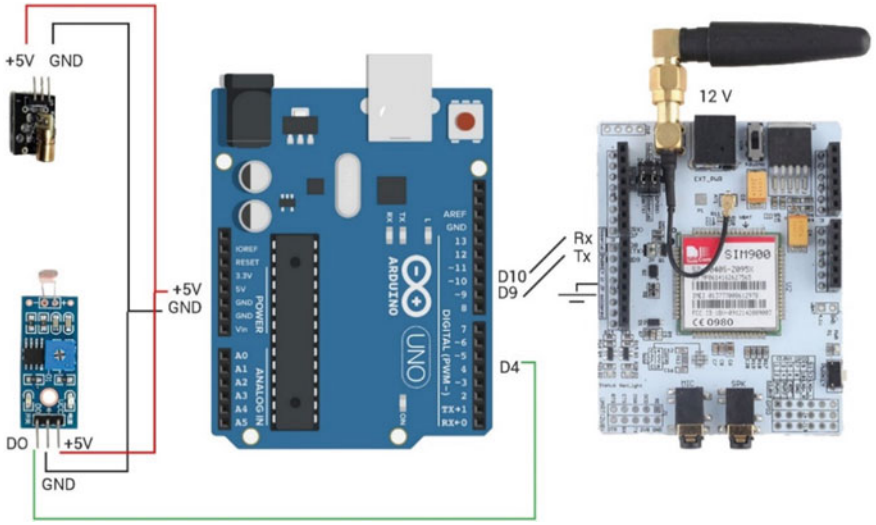

Fig. 4 Circuit of a safety dispatch system

Sensors The sensors used in the circuit are the laser module as transmitter and LDR as a receiver. The laser emits a beam of which is received on the LDR and the trip wire is set up. Upon calculating the speed and time, a preset interval is programmed to the Arduino exceeding which the trip wire will send and alert through GSM. The combination of both the sensors on road is the novelty of the system and can be used to detect and report incidents and prevent mishaps on a large scale as well.

The below schematic in Fig. 4 highlights the proposed design of the safety dispatch system. It essentially consists of three lasers as transmitters and LDRs as receivers which act as trip wire built on an Arduino and mounted on the accident prone road. When a vehicle cuts the trip wire for longer than the specified time, representing the abnormal conditions, the GSM module through AT command sends texts containing the location of the system and thus reporting the incident to the authorities. The adjacent flowchart shows the conditions for which the Arduino triggers the GSM module. The innovation aspect of the design is the fact that the system is built to be installed on roads and hence being affordable to all (Fig. 5).

The flowchart in Fig. 6 pictorially represents the algorithm on which the code for the system was developed using the Arduino IDE framework

3 Prototype Demonstration

The following circuit diagram represents the proposed hardware connections and prototype results of the systems used (Figs. 7, 8, 9 and 10).

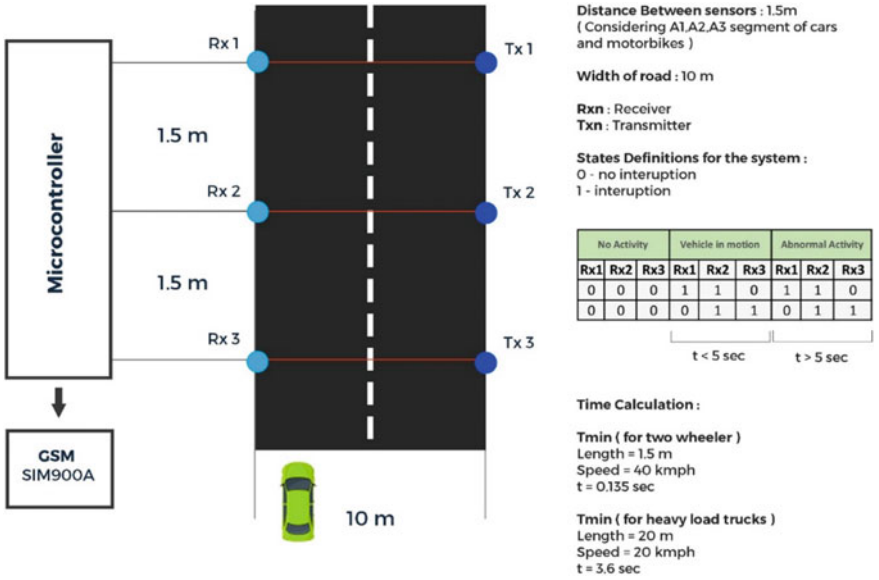

Fig. 5 Schematic of the design of safety dispatch system

4 Conclusion

The aim of the work was to design and implement a microcontroller-based smart street lighting and safety dispatch system for smart city applications. While many methods exist for the very purpose, the proposed system uses a new sensor, HB100 and the implementation of the safety system on the roads was a novel approach to make road safety systems more accessible to all kinds of vehicles and all class of people. Arduino boards have been used to achieve our circuit design where the microcontroller helps in the detection of pedestrian or vehicle movement by processing the information given by the sensor. Another microcontroller is used for the safety system where it processes inputs from the laser trip wire circuit and prompts the GSM module to send location text messages.

The coding for the circuit was done in C using the Arduino IDE platform. Satisfactory results were obtained by testing the above implemented model. An obstacle was detected and street lighting was switched on. And, in case of an accident detection, the GSM module sent a link of location, fed into the system helping in quick detection and dispatch. For future work, the following model can be extended and made more accurate by using a more efficient and accurate sensor for lighting, and the safety system can be made more reliable by sending pictures or live feed of the accident location using camera devices.

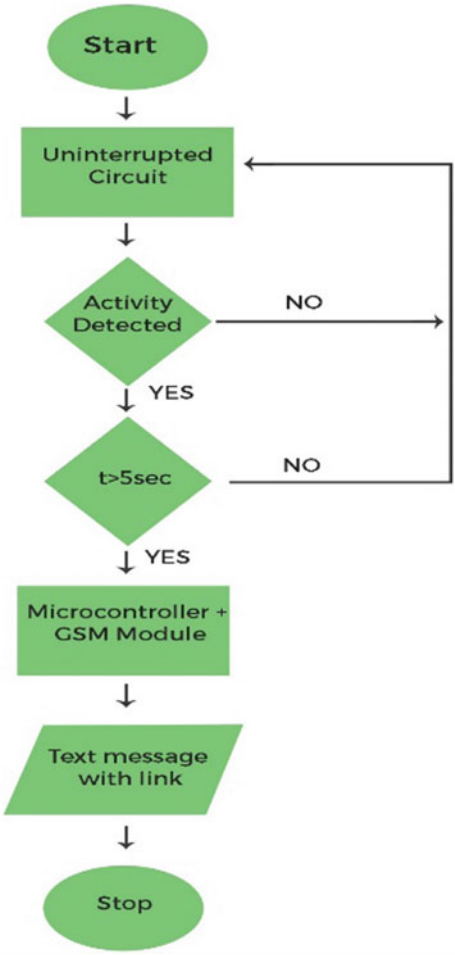

Fig. 6 Flowchart for the process of accident detection in the smart safety system

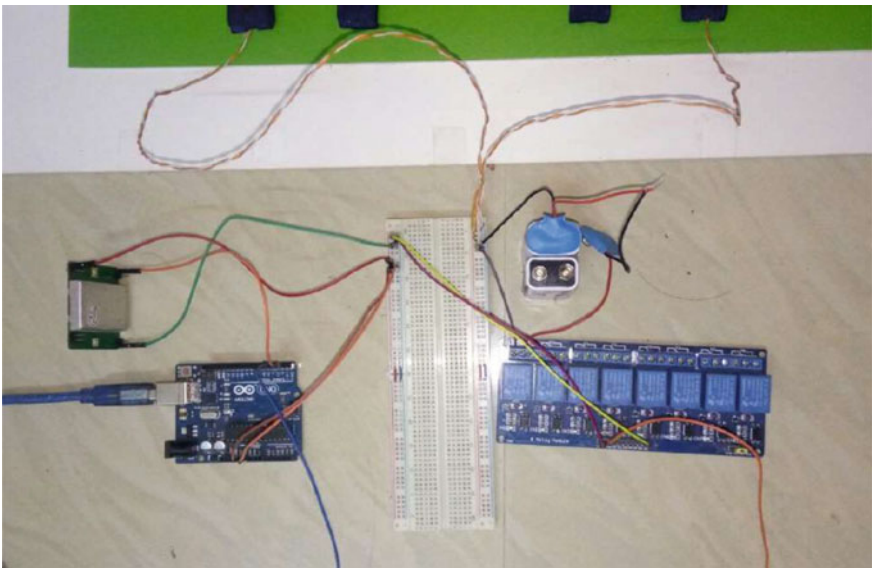

Fig. 7 Hardware assembly of a smart street lighting system

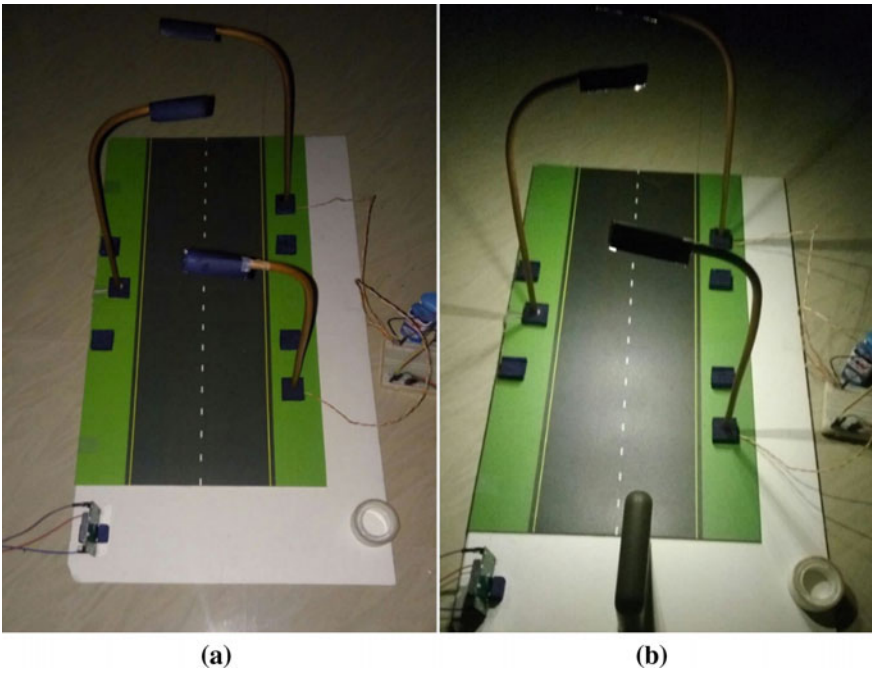

Fig. 8 **a**. No obstacle detected by sensor and lights remain switched off, **b**. Obstacle detected by sensor and switching of lights

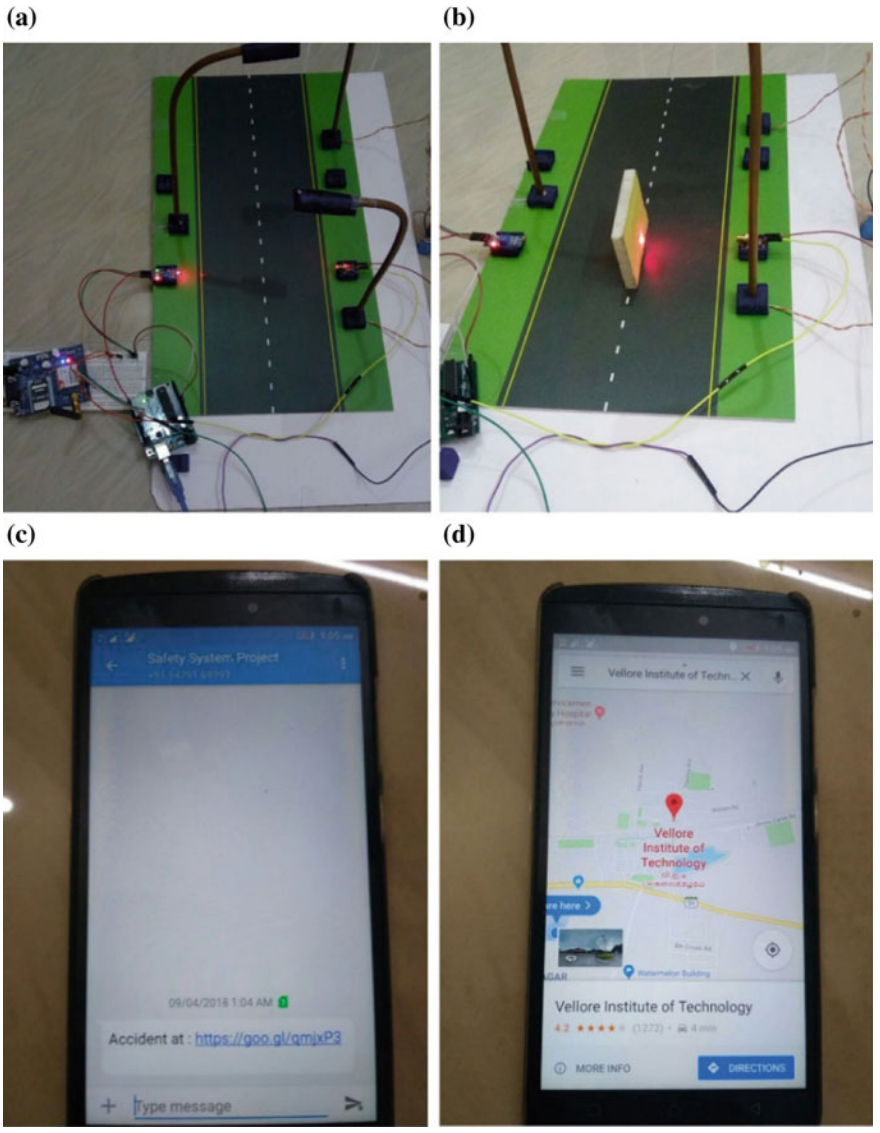

Fig. 9 **a** Safety system when no abnormal condition detected (top left). **b** Safety system when obstacle detected (top right). **c** link of accident location on mobile (bottom left). **d** location opened in google maps (bottom right)

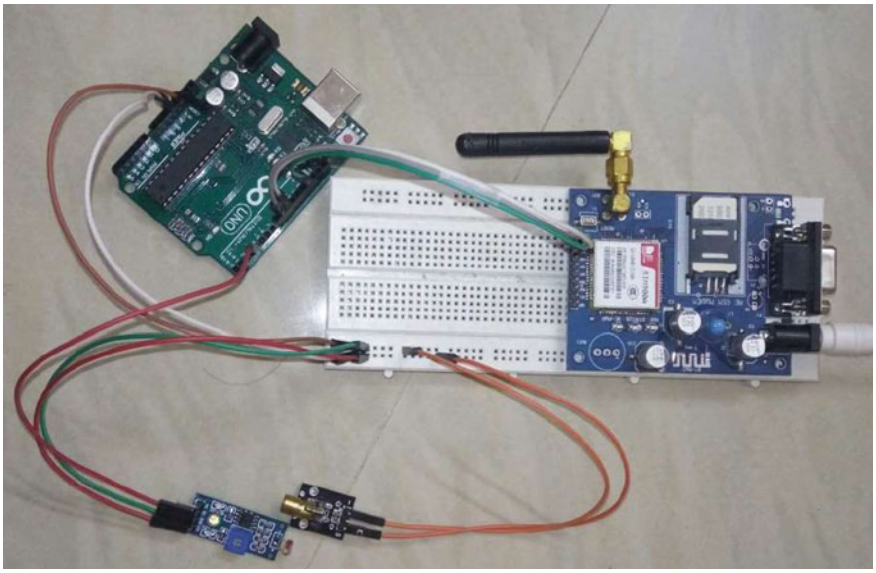

Fig. 10 Hardware assembly of a safety dispatch system

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