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IoT Based System for Accident Detection, Monitoring and Landslide Detection Using GSM in Hilly Areas

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Abstract: This paper described the detailed study for the detection and monitoring of accidents in hilly areas. In the past few decades, road accidents are a major cause of death in suburban hilly areas. These accidents not only affect the life of the destitute but also affect the lives of others. Over the last few decades, hilly areas are now ideal locations for holidays, hence an adequate number of travellers are moving towards hill stations for enjoying free time. This movement also invites accidents to occur due to bad driving skills, blind turns, overspeeding, etc. Also, during the peak time of holidays, abrupt climate change occurs and leads to heavy rainfalls, which are the major cause of landslides. As a result, the loss of life of travellers and blocked roads affecting transportation of necessary goods occur in hilly areas which affect the development and living of other people. Internet of Things (IoT) system may be a better solution to detect monitor and prevent these accidents and landslides. IoT system consists of sensors, actuators, a powerful micro-controller, and a network interface. This system detects and monitors accidents and landslides and informs the command centre about the location. Implementation of the IoT system helps us to lower the accident rate and easily locate the affected areas of landslides using global service for mobile (GSM) or Wireless Fidelity (Wi-Fi) connectivity. It is always a challenging task for a rescue team to locate the exact area of an accident and carry out life-saving operations.

Keywords: IoT, micro-controller, GSM, Wi-Fi, hilly areas

1. Introduction

In the past few decades, the tourism sector has gained enormous popularity among youths and urban families. To enjoy nature and spend holidays from a hectic 21st-century schedule, most peoples opt for a way towards hills and mountains. This new travel trend section also influences young age teenagers to earn while exploring nature through video shoots and vlogging. Also, the tourism sector is a source of revenue for the state economy. This boom in tourism also invites various risks at an alarming rate. To improve tourism, various mountains were sliced to pave roads, and various small tributaries of river paths have been forcefully changed. Hence collectively, it resulted in the formation of natural disasters like landslides, cloud bursts, and uneven rainfalls.

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According to the research of Transportation Research and Injury Prevention Centre [1] and based on official statistics, 1.5 lac persons were killed and 4.7 lac injured in road traffic crashes in India in 2018. However, this is probably an underestimate of injuries, as not all injuries are reported to the police. The number of cars and motorbikes in 2016 was 30.2 million and 168.9 million respectively. The total number of deaths in 2018 was 10 times greater than in 1970 with an average annual compound growth rate (AACGR) of 6%, and the fatality rate in 2014 was 5.2 times greater than in 1970 with an AACGR of 3.9%.

Now with the exploration of technology, these accidents are easily monitored, location can be easily detected and prior alarms can be issued before natural disasters. Internet of Things (IoT) [2] systems come with an exceptional benefit that is suitable to handle such conditions and inform the local authorities about such mishappening.

IoT [2] system consists of various sensors, actuators to improve signal strength, a micro-controller for better computation and logical operations, and a network device for providing connectivity. A suitable regulated power supply is also needed in the system for undisrupted power.

This research paper contributes to the deployment of IoT [2] systems in hilly areas for monitoring detection and prevention of accidents and landslides which took place very frequently in hilly areas and regularly affect the living of hilly residents. Implementation and deployment of IoT [2] systems are very easy and cheap. Different sensors are included in the design for better working of the module and proper data collection. Notification panels were also included in the setup which indicates recent accidents in hilly terrains. The power supply is an important aspect for these modules to work, hence battery and secondary power sources are arranged in the system for continuous power supply. A powerful STM32 controller is used, which is designed by STMicroelectronics, for IoT [2] operations. Different sensor modules like rain sensors, vibration sensors, sound and shock sensors are used for the detection of accidents and landslides and a fully mature network unit consists of global service for mobile (GSM) [3-6] or Wireless Fidelity (Wi-Fi) (depending on network availability) is used to put the accidents alerts on the server.

The rest of the manuscript is organized as follows. Related work is discussed in Section 2, the proposed methodology is elaborated in Section 3, the working system of the proposed methodology is presented in Section 4, experimental results and discussion are stated in Section 5, conclusions are committed to Section 6.

2. Related work

In India, where a diverse geography exists, it's very important to design and deploy road safety equipment with the consideration of terrain. In the north where high mountains lie and in the south where a hot and humid climate exists, the same IoT [2] system is not a good idea. A road safety system should be designed in such a way that it can handle the climate conditions in particular areas. Sensor units can also be modified based on the geographies, for example, vibration sensors are not needed in plane areas, and moisture sensors are not needed in hilly areas. To understand the root cause of accidents in hilly areas, various articles have been reviewed and accident report has been studied.

Singh and Talapula [2] was the first author who proposed an IoT system for traffic monitoring and tracking system in hilly regions. But the drawback with their proposed method is the high cost, complex system, and not suitable for major deployments. The number of devices equipped in hilly terrains depends on the reachability of any accident. Hence, if the cost per unit device is high then its deployment of the units would be less, hence resulting in less reachability. Micro-controller used in the device should be cost-effective and limited to only those communication protocol stack which is required in the proposed work. Apart from micro-controller cost, sensor, and other peripherals cost also plays a key role in overall device cost.

Ramachandran et al. [7] proposed another method for accident prevention in hilly regions. They proposed in their research paper that if there is a vehicle on the opposite side of a blind turn then another side vehicle would get a notification and control its speed. The proposed method is cost-effective but the limitation of this method is that it only indicates the speed and the presence of the vehicle, it would not indicate the accident. The limitation of this approach is the scalability of the accident. The accident is not monitored over the cloud using this approach. Recently, in the year 2020, Pautare et al. [8] proposed a method to identify the location of landslides in hilly areas using wireless sensor networks (WSN) and IoT. They proposed a mesh network approach to detect landslides and other major natural disasters in hilly areas. The limitation of this approach is that it is only limited to landslide detection, not monitoring vehicle accidents. Another limitation is that there is no central server available for remote monitoring of the accident.

Choubey et al. [9] have used Internet Protocol (IP) technology in WSN for the accomplishment of the IoT version. They have used IoT/Machine-to-Machine (M2M) protocol for application data transfer.

Bergonda et al. [5] in their study proposed a Global Positioning System (GPS) based IoT method for vehicle accidents, detection, and tracking system. The proposed method works well for plain areas whereas, in the case of hilly areas, this approach needs to be enhanced because of the different terrain. Hence, limitation is the geography and its integration with the system.

3. The proposed methodology

The architecture of the proposed methodology is depicted in Figure 1. The module in our proposed work is based on an arm-cortex micro-controller and uses a development board named ESP-32 board [10]. This board is equipped with various sensors and a stable power supply option. This board is also equipped with Wi-Fi and an inbuilt Bluetooth Low Energy (BLE) card, so if there is an issue with the Wi-Fi range then BLE will come into play.

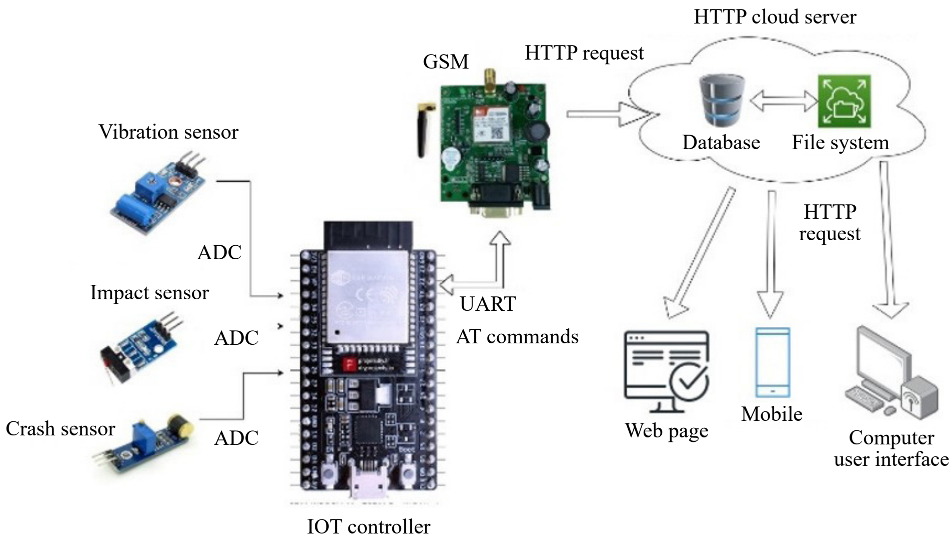

Figure 1. The architecture of the proposed work

Using this board, different sensor units are also interfaced, so that the actual value is captured. Sensors are a vibration sensor [11], a shock/crash sensor [12], and an impact sensor [13]. All these arrays of sensors are calibrated with the actual threshold values and connected with the micro-controller. The value captured by the micro-controller is screened and if the value is more than the threshold value then data is sent to the Wi-Fi module in the form of Hypertext Transfer Protocol (HTTP) [14] requests. These requests are executed and collected data samples are sent to the cloud setup.

Cloud setup is having a proper database to store the information received and based on the device identifier (ID), the location of the device ID is fetched and sent to the zonal office for the rescue process. The whole process is executed within a minute so that valuable life can be saved.

4. The working system of the proposed methodology

The working system starts with the sensor array. The sensor array consists of 3 sensors: a vibration sensor, a crash/shock sensor, and an impact sensor. These sensors pick the data of corresponding vectors where the vibration sensor picks the vibrational data of mountains, the crash/shock sensor picks the crash force of vehicles of road barricades, and the impact sensor picks the sound value of vehicle face-to-face impact.

After collecting these values, these values are given to the analog-to-digital conversion (ADC) module of the controller. Here, ADC used is SAR ADC as depicted in Figure 2. SAR is an acronym for successive approximation register. It is one of the types of ADC used in embedded systems. It uses a series of comparisons to determine each bit of the converted result. It requires one extra clock pulse as per the number of bits of ADC. Suppose we are using ADC having 10 bits configuration then the number of clock pulses we need in SAR ADC should be 11.

Working of SAR ADC involves two inputs, the first is analog input from the sensor with a sampling capacitor and the other is test value input with a digital-to-analog converter (DAC). These inputs are compared using a comparator and output is determined depending on the values of inverting and non-inverting input values.

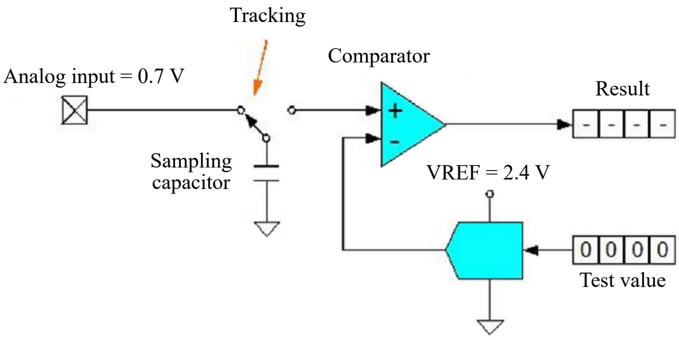

Figure 2. SAR module

The value is captured and the resolution is set as per the signal strength. Once the pre-configuration is performed, values are checked and compared with the threshold values. If the sensor value is above the threshold value, then the defined interrupt is activated.

This interrupt will trigger the service routine of interrupt which primarily setups the GSM modem. GSM modem is used to provide the connectivity of cloud services to the IoT system using AT commands. GSM modem works on a pre-defined set of AT commands and on the reception of AT commands, GSM modem works. The interface of the GSM modem with the IoT controller is achieved with the UART protocol.

UART stands for Universal Asynchronous Receiver Transmitter. This protocol is used in communication modules where no clock is required. It is an asynchronous protocol, that uses a defined baud rate and TX-RX pin connection. TX-pin of the IoT controller is connected with the RX pin of the GSM modem and the RX pin of the IoT controller is connected with the TX pin of GSM.

Once the GSM modem is interfaced with the IoT controller, AT commands to activate the General Packet Radio Services (GPRS) connection are executed. GPRS and UART connection allows IoT controller to use the internet on the controller and post data to HTTP cloud. HTTP cloud server has two sections named, Database System and File System. The Database System, as shown in Figure 4, performs the operation of saving the data in the form of tables. In the tables, various columns are designed as per the data coming from the controller such as device ID, sensor values, latitude longitude location, data time values, etc.

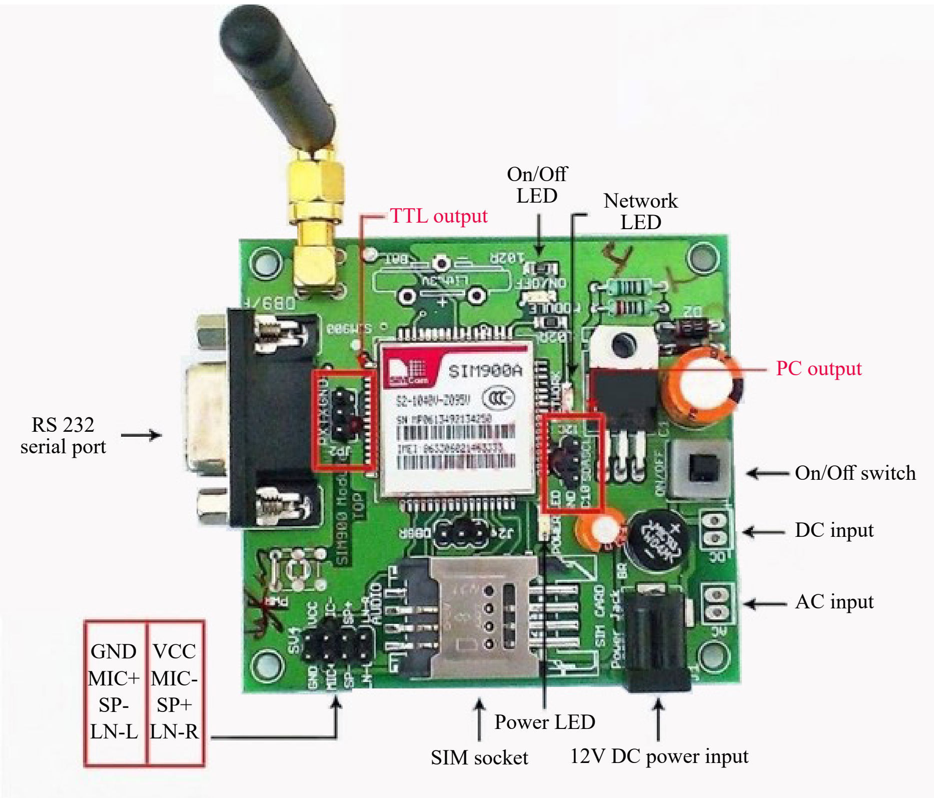

Figure 3. GSM module

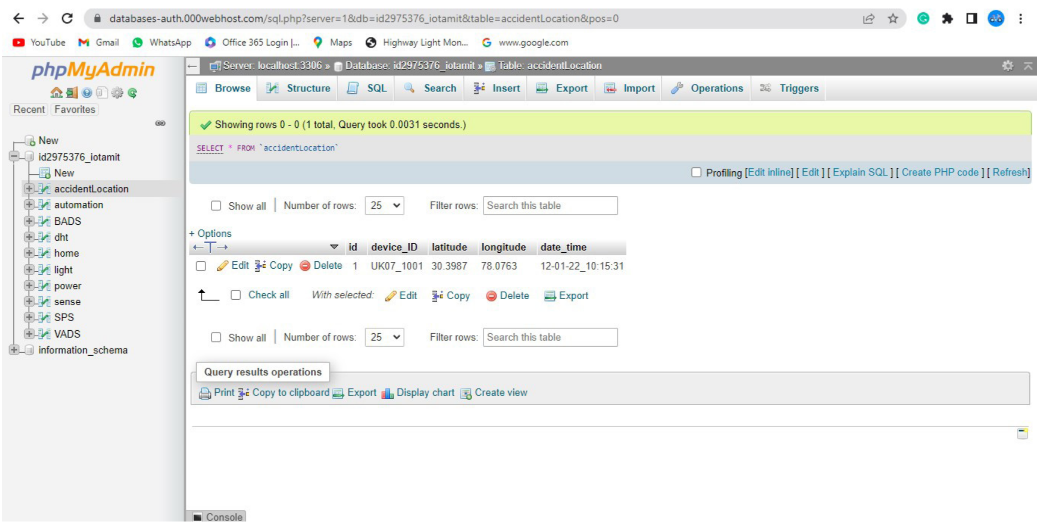

Figure 4. The Database System of HTTP cloud

Another section of the cloud is the File System as shown in Figure 5. This is used to fetch and insert the operation of data into database tables. Data are fetched and inserted into rows of tables depending on which device request is received. Hence, after the data operation is executed, information is sent to the local authorities on a mobile application, web interface [15], and desktop graphical user interface (GUI). These data contain information about the accident location, date and time, device ID, and cause of the accident.

Data are stored in the database which is configured during the project setup and the size of the table should be dynamic which can be extended with the number of locations and the number of accidents. Data coming from hardware devices are received by the application programming interface (API) which handles the incoming data and passes it into variables. Now, these variables are used to hit an INSERT command which appends data to the database table.

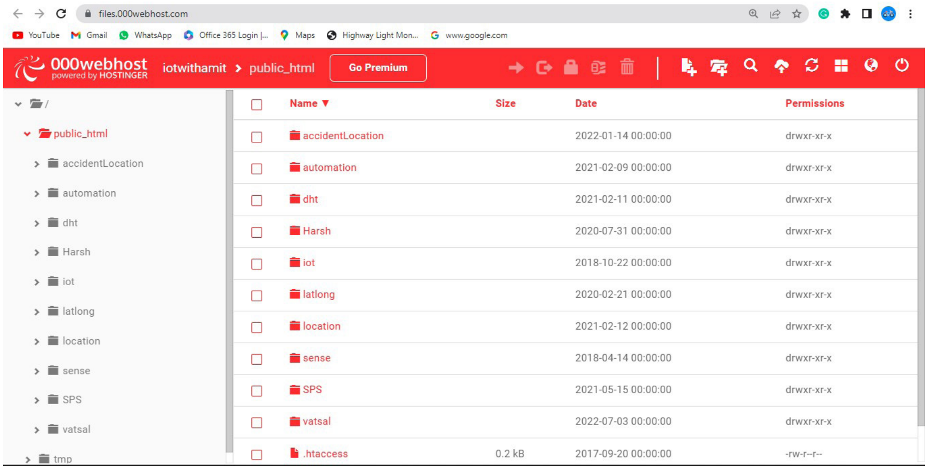

Figure 5. The File System

Once data is available in the database, it can be used to display the location via Google Maps API as shown in Figure 6. We can plot various graphs to know peak time and weather during the accident happens using different existing algorithms. We can develop proper rescue operations during these timelines. Data from these databases are again fetched using an API, and fetched data is shown in JSON format.

These JSON formats are highly used in web designing and they could also be used by the user device such as mobile apps and GUI. Now, entire HTTP server should be parked on some web hosting platform to become visible or live for all the users.

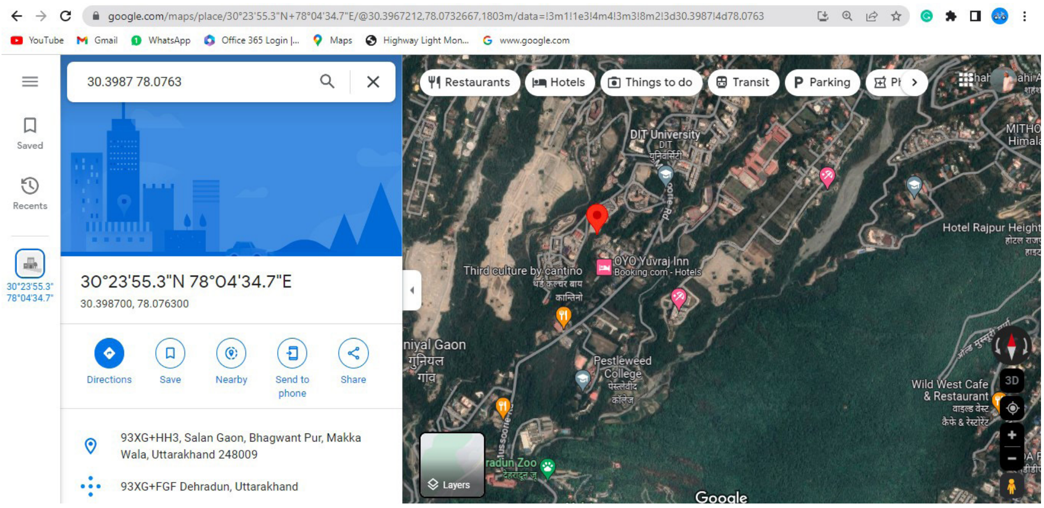

Figure 6. Output on Google Maps

5. Experimental results and discussion

After assembling all the modules and hardware, we flashed C program code into the micro-controller, we also configured the HTTP cloud and hosted it on a web hosting channel. Once data is sent from the micro-controller to the cloud, data is visible to everyone in the form of a table. Data visualization can be changed as per the need of the end user. Data displayed on the web contains latitude, longitude, and date time information as shown in Figure 7. It also contains a hyperlink to redirect the page to Google Maps to locate the exact location of the accident.

Users can mark the place and using Google Maps, they can find the shortest path to reach the location on time. Multiple data can be received on the server from multiple devices, to map data with the device we are using the device ID which is the identity of every individual device. The data table has multiple rows containing device ID, latitude, longitude, date and time, and a hyperlink to redirect to Google Maps for location.

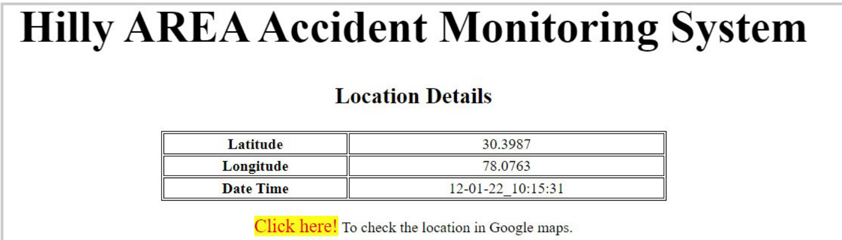

Figure 7. Output web page

6. Conclusions

The proposed system is about to detect landslides and accidents in hilly areas and if there is some mishappening then data is collected and sent to the cloud. Now, cloud script will analyze from which device data is received and identifies the location of the device. Each device is mapped with a fixed device ID and device location.

Cloud will send the location to the local authorities for the proper rescue process. Location can be tracked using the Google API and using Google Maps route can also be decided. Modification can be done further to enhance the working of the proposed model and to meet further challenges.

Conflict of interest

The authors declare that there is no conflict of interest.

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