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Machine Learning and IoT based Smart School Bus Tracking with Accident Surveillance

Samrin Khan[1], Vijay M Purohit[2]

[1]Student, Dept. of Electronics & Telecommunication Engineering, VIT, Maharashtra, India
[2]Professor, Dept. of Electronics & Telecommunication Engineering, Vidyalankar Institute of Technology Maharashtra, India

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Abstract - *Millions of children use school transportation worldwide. We need an effectively reliable, safe and smart transportation solution. The proposed system portrays a transportation concept providing live tracking, calculates optimized routes to destination, detects intrusion and helps maintain the statistical data of transportation system. The IoT network is formed using IR sensor and RFID Tag. Intrusion detection is carried out using facial recognition. Live position detection is achieved using Google Maps, GPS and accelerometer data. A Raspberry Pi micro-controller mounted on the bus communicates with a centralized Firebase cloud platform. The mapped data can be accessed on a mobile application by admin and parents. The system stores vital information like driving skills, attendance analysis and best-routes. The data is effectively used in ML optimizer. Alerts are sent to caretakers in case of emergency situations. This idea aids the admin, parents and driver to manage and make accurate decisions.*

Key Words: IoT, IR sensor, RFID, Raspberry Pi, GPS, Cloud, Google Maps, ML

1.INTRODUCTION

Kids travelling to and from school is a crucial concern for parents. Numerous issues occur like waiting long time for delayed bus, kidnapping and students deboarding at the wrong stops. Other issues include lack of information about the routes taken by the school bus to reach the destinations, preventing unauthorized person entering bus. Safe-guarding the students has always been a priority especially for working parents whose solution must be consistently improved [1]. If a student is missing, drivers may not be able to identify all the students on time. Carrying mobile phones in school premises is often not permissible for children. It is inconvenient for the school authorities to reach each parent regarding their child's safety. [2]. The driver should be aided for safe driving and caretakers should be warned if driver is involved in rash driving [3]. Internet of Things provides a much better solution to ensure the student's safety by tracking and monitoring them.

To address and overcome these concerns IoT is embedded as the principal concept. The proposed system provides web-based bus tracking system. An IR sensor set at the entrance detects students entering the bus and verifies it through RFID reader. For identification and information retrieval the RFID device is scanned. Every student wears their particular tag while entering into the bus to scan their tag on the RFID reader. On verified scanning, parents and admin get notified regarding their child boarding the bus. Further attendance gets updated over the Firebase using Raspberry pi micro-controller. In case scan mismatch occurs, notification is sent over Firebase for detecting an intruder and capturing intruder's photo. Every child gets detected when boarding or deboarding the bus.

The Accelerometer monitors the bus state and analyses the driving behavior. The system tracks the child's location and bus-route in real-time. The GPS module tracks the vehicle. The Overall system monitoring is based on the GPS location, driver's behavior and emergency conditions. If an accident or emergency occurs then caretakers would be notified immediately. All the monitored data would be stored over Firebase for future access.

1.1 Literature Survey

F Judy et al. [4] proposed a school bus monitoring system utilizing RFID and GPS for attaining connection to a remote server over Wi-Fi embedded with an ESP8266 micro-controller. Information was accessible to caretakers using the Cloud-based Firebase messaging service. A vehicle monitoring system was introduced by Jisha et al. [5] for school children used GPS and GPRS/GSM technologies ensuring security to the students, which consisted of an Internet-enabled android application which interacted with a server.

W. Pattanusorn et al. [6] developed a system which registered the children information at the entry-level automatically when they surpassed the scanner. SMS notified parents about their children entry/exit information from the school bus. H Eren et al. [7] put forth a driving behavior analysis approach which used the sensory data. The tracking was conducted via a smartphone in order to represent a car-independent system not requiring vehicle mounted sensors. An android based framework which coupled GPS information with Google maps data to precisely discover the location of the missing mobile phone was suggested by Muneer et al. [8]

Need for the development of a real-time transportation-based information system for the users, which could aid in better travel plan and lower waiting time for the buses developed a sense of motivation. Minimization of the waiting time is possible with real-time data processing that shows alternate paths to soothe the commuters arrive their destination faster. For expanding security framework and traceability aspects of the child the proposed work utilizes IoT with RFID, Raspberry Pi, IR sensor, GPS, Firebase, Google Maps to achieve features including attendance analysis, notifying end-users with alighting and boarding alerts, location tracking through GPS by integrating Google Maps, intrusion and accident detection along with driving behavior analysis and cloud storage. This information would be accessible to admin, parents and driver through the mobile application.

2. COMPONENTS

The proposed system utilizes the following hardware and software components:

2.1 Hardware Specifications

The hardware to be installed on the bus is the integral and most important component. This section introduces the hardware used for prototype development which includes the following:

A. IR Sensor

Measuring and detecting infrared radiation in the surrounding atmosphere is the key role of IR Sensor. In the proposed system IR sensor is utilized as the first step of verification of student's entry into the bus. An IR Sensor module possesses an adaptable potentiality of the atmospheric light with a pair of infrared transmitters and the receiver tube. Infrared technology deals with a huge number of wireless applications.

B. RFID Reader RC522

The RFID RC522 Card Reader Module is a low-budget 13.56 MHz RFID Reader Module based out of MFRC522 controller. A power supply of 3.3V is required by the module. It can communicate directly with any CPU board by connecting through the SPI protocol and also supports I2C & UART. It is used in the proposed system for attendance analysis and person identification purpose.

C. Raspberry Pi 3 B+ Micro-controller

The Raspberry Pi is a single computer board developed to put forward programming and computing concepts. It possesses a 64-bit quad-core processor which runs at 1.4GHz and dual-band 2.4GHz. It consists of 5GHz wireless LAN and Bluetooth connectivity making it an absolute solution for powerful connected designs. It brings on high processing power along with on-board connectivity making it best suited for IoT applications.

D. Camera Module

A custom designed add-on for Raspberry Pi is the 5-megapixel Camera Module Rev 1.3. A dedicated CSI interface is used which is especially designed for interfacing to cameras. Significantly high data rates and absolutely carries pixel data are provided by CSI bus. It is used in the proposed system for capturing the snapshot of the intruder.

E. GPS Module –Neo 6M

The Neo-6M GPS module is a well-operating GPS receiver with a built-in 25 x 25 x 4mm ceramic antenna. It comes up with a strong satellite search capability. The status of the module can be monitored with the power and signal indicators. It is used to read geographical parameters.

F. Accelerometer –MPU6050

The MPU6050 consists of 3-Axis accelerometer and gyroscope both integrated on a single chip. Owing to the three accelerometer and the three gyroscope outputs it is also known as a six-axis motion tracking or six Degrees of Freedom (DoF) devices. Fig-1. represents hardware components utilized in the development of the prototype.

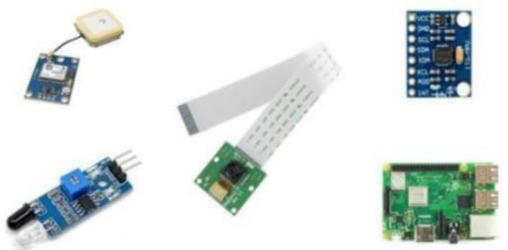

Fig -1: Hardware Components

2.2 Software Specifications

The android app was generated using multiple web development technologies including HTML, JS, CSS, jQuery and Bootstrap. The Google Maps API have also been integrated in the app to view the live location. The real-time updates were fetched by utilizing Firebase fire-store. To wrap this view in an app, we used Apache Cordova.

A. Firebase

The Firebase is a cloud-hosted database which enables storage and syncing of data between users in real-time at a global level. It encourages user's collaboration and building serverless apps. The NoSQL database are stored in JSON format. Realtime Database instance can be shared with all the clients while building cross-platform apps. The data remains available even when the app goes offline.

B. Google Maps API

Google has developed application programming interfaces that enable communication with Google Services and their integration to other services. The functionalities include analytics, machine learning as a service and accessing the user data. Google Maps can also be embedded on a website or app. Adding relevant content for users and customizing their map view according to the site is possible. It is used to add a map to the Android app in the proposed model to identify routes the bus travels and provide the best path to destination with real-time traffic updates.

C. Node-RED

For collaborating the hardware components, APIs and other online services Node-RED is widely utilized visual programming tool which provides a browser-based editor. The flows can be stored using JSON and shared with others. They can be employed to its runtime on a single-click. It is basically built on Node.js and is an event-driven and nonblocking model. In the current system it is deployed with the Raspberry Pi.

D. Bootstrap & jQuery

Bootstrap is a front-end framework for developing web applications. With the help of HTML and CSS consistency is maintained across different browsers and device screen sizes. It provides a huge number of themes and plugins. jQuery being an open-source medium is used to design the client-side scripting on HTML making the website applications much responsive.

E. Apache Cordova

Apache Cordova is an open-source mobile development framework. It enables us to build hybrid web applications by using HTML5, CSS3, and JavaScript. It is responsible for connecting the web-based applications with native mobile functionalities. It acts as a bridge that develops the connection between web applications and mobile devices.

3. PROPOSED SYSTEM ARCHITECTURE

The proposed system aims to provide effective services using a fusion of different technologies with IoT. The diagrammatic representation for the proposed system is demonstrated in the Fig-2.

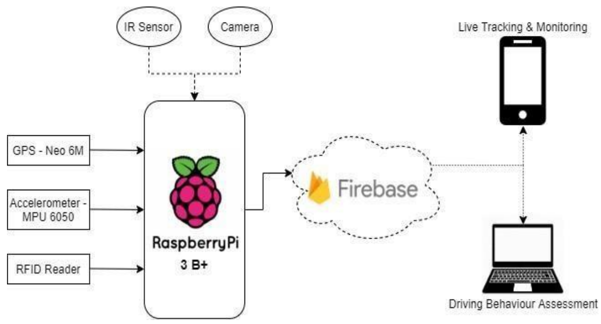

Fig -2: Proposed System Representation

The hardware prototype of the system is displayed in Fig-3. It highlights the different blocks that have utilized to build the prototype. The Raspberry Pi acts as the brain of the entire system, which is connected to different sensors such as GPS, Accelerometer, RFID, IR and Camera. It is also connected to Google Firebase for maintaining databases. Most of the data is in sync between the Raspberry Pi and the Firebase.

The mobile apps are built for the admin, driver and parents to always stay updated with the latest information such as routes, live tracking, attendance and alerts.

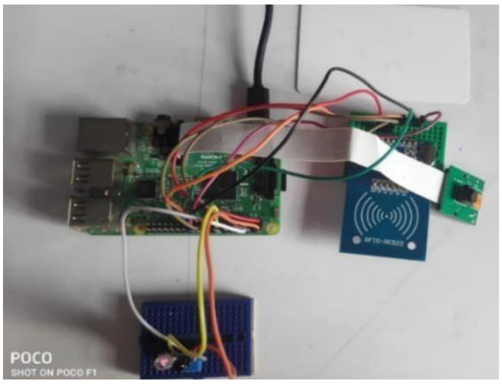

Fig -3: The Hardware prototype

The accident detection approach is developed on the basis of Random Forest Machine Learning Classifier shown in Fig-4.

Random Forest is an in-demand algorithm of machine learning belonging to the supervised learning technique. Classification and Regression problems in ML are resolved using this algorithm. It is based on the concept of ensemble learning, which is a process of combining multiple classifiers to solve a complex problem and to enhance the performance of the model.

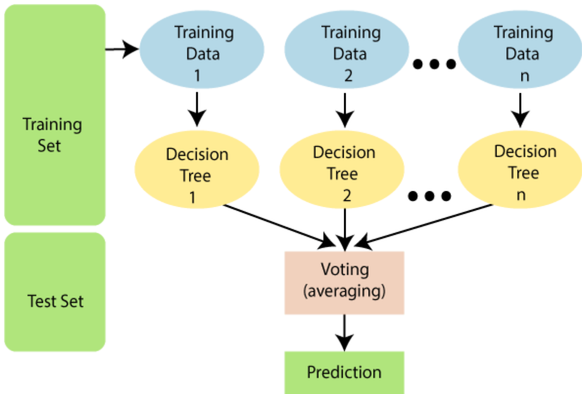

Fig -4: Working of Random Forest Algorithm

As the name suggests, "Random Forest is a classifier that contains several decision trees on various subsets of the given data set and takes the average to boost the predictive accuracy of that data set". Rather than relying on one decision tree, depending on the majority votes of predictions, the random forest classifier gathers the prediction from every tree to predict the final output.
The more significant quantity of trees in the forest leads to higher accuracy and prevents the problem of over fitting.

As described in Fig-4. the Random Forest algorithm relies on two-phase; first is to create the random forest by combining N decision tree, and second is to make predictions for each tree created in the first phase.

The Working process is illustrated in the below steps and diagram:
Step-1: Selection of random K data points from the training set.
Step-2: Build the decision trees associated with the selected data points (Subsets).

Step-3: Choose N number for the decision trees to be build.
Step-4: Repeat Step 1 & 2.
Step-5: For new data points, find the predictions of each decision tree, and allocate the new data points to the category that wins the majority votes.

The implemented architecture algorithm outlining the complete flow is portrayed in Fig-8 in the Section 4. It highlights how the different entities (hardware & software) interact with each other. An IR sensor detects students entering the bus by verification through the RFID reader. After successfully verifying, the tag data is uploaded to the cloud making use of a Raspberry Pi micro-controller making it can be accessible for admin, parents and driver over a mobile application. This assists in obtaining attendance analysis for parents and school authorities. The camera is deployed to detect the possible intrusion in case RFID reader is not detected. The snapshot of the person is captured at that time. The information from accelerometer and GPS module are collected and pushed to the cloud throughout the trip. The GPS-based information with Google maps data makes it possible to track the geographic coordinates of the vehicle's location as well as the speed. Accident detection is accomplished using Machine Learning information from the driving behavior analysis, ensuring student's safety. The driver can be approached by the administration in case of emergencies.

4. RESULTS

As part of the pilot study this section builds the results and inferences. The design implementation has bus route comprising of three stops. The data was fetched for duration two months (February and March 2020). The inferences concluded from the analysis and experiments include traffic pattern, the driving pattern and also identification of possible bottlenecks in that route. In the data for the proposed system were collected through GPS units fixed within school buses.

The experimental route selected was from Vidyalankar Institute of Technology, Mumbai to Matunga Railway Station, Mumbai which spans 3.6 km. There are nine bus stops on this route. Every 60 seconds, GPS data, from the device, installed in the buses, was sent to a server. GPS data included the latitude, longitude, speed and time stamp.

In order to make a real-time prediction of the time of arrival of the bus the data received in the server was processed immediately. The data from previous days and the current bus stop's real-time data received from GPS receiver were utilized to predict the time of arrival of the next bus stop. The mobile app allowed tracking of attendance as well as the live location of the bus along with alerts (for intrusion detection and accident detection).

The Fig -5, 6 and 7 represent the outputs achieved for RFID scanning, student detection and intruder detection respectively.

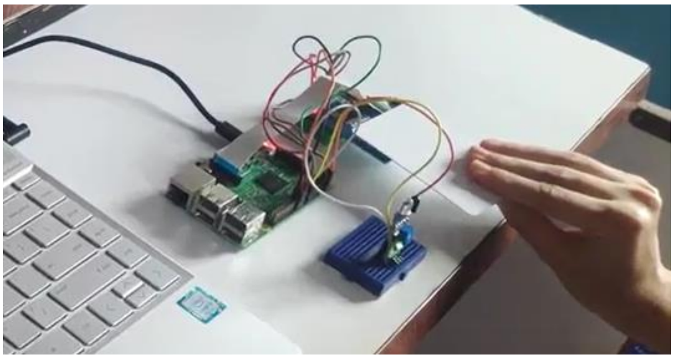

Fig -5: RFID Scanning process setup

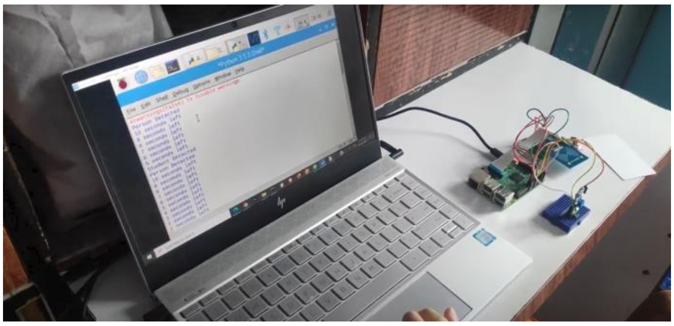

Fig -6: Student detected on successful scan

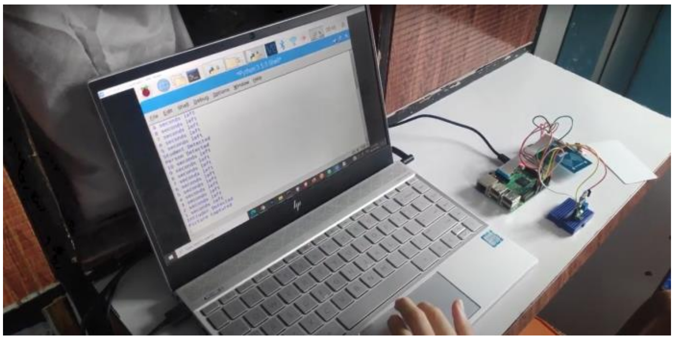

Fig -7: Intruder detected on unsuccessful scan

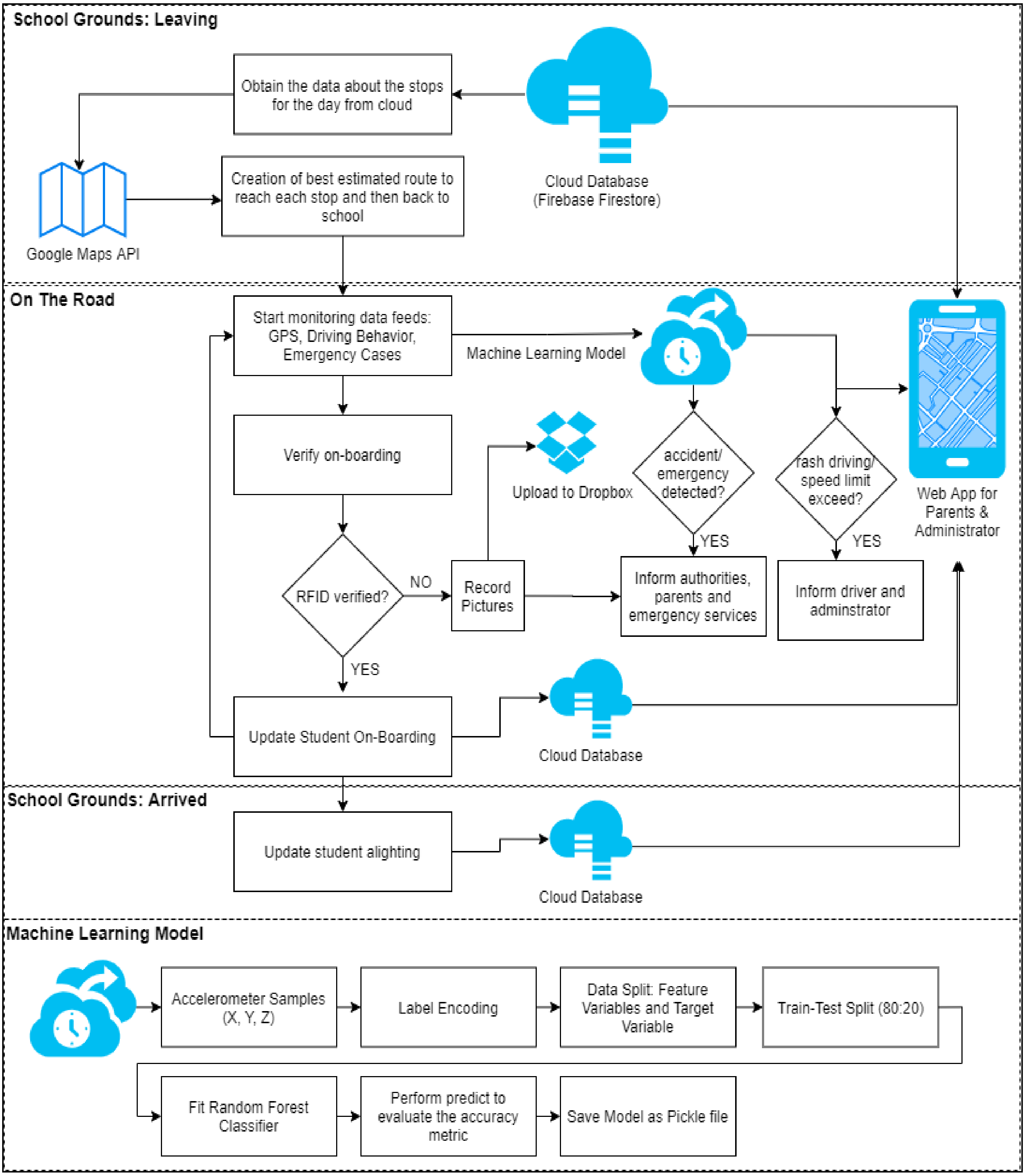

Fig-8: Algorithm model

The implementation algorithm as can be seen in Fig-8 has been divided into three parts to demonstrate the working easily. From the top the data about the stops and best estimated routes are analyzed using Google API and stored on the cloud database. RFID is setup for student and intruder detection. Picture of intruder is recorded, stored and notified on cloud. Accelerometer is used to calculate and analyze driving behavior for accident detection using Machine Learning model.

Fig-9. below interprets the mobile application showing different views of the proposed implementation.

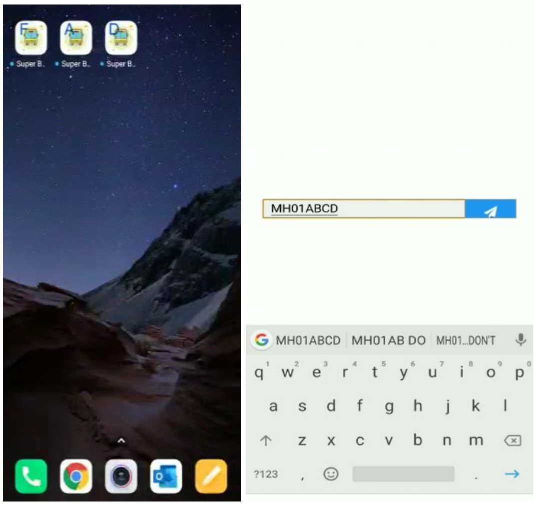

Fig-9: 3 Apps and a snap entering bus details Tabs

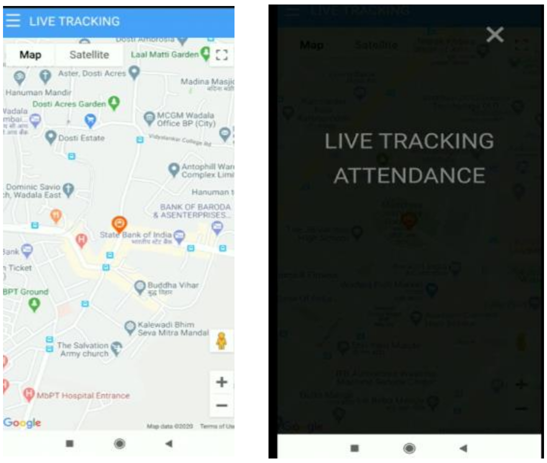

Fig-10: Live Tracking Tabs

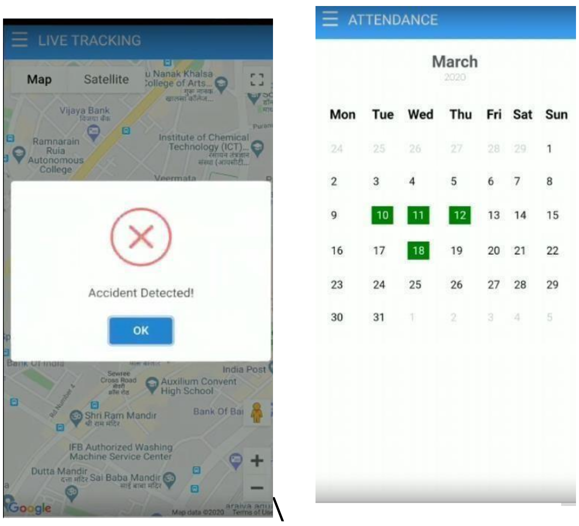

Fig -11: Accident detection and Attendance view

The graphs in Fig-12 below shows accelerometer data for accident detection for different samples (X-Axis – Timeline & Y-Axis – G Values).

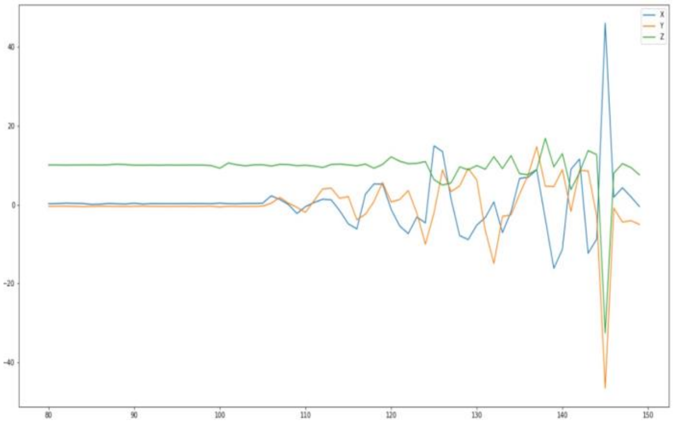

Fig-12a: Sample Data 1

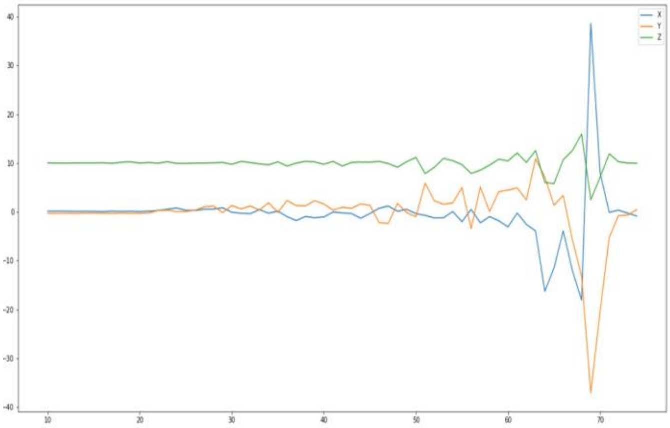

Fig-12b: Sample Data 2

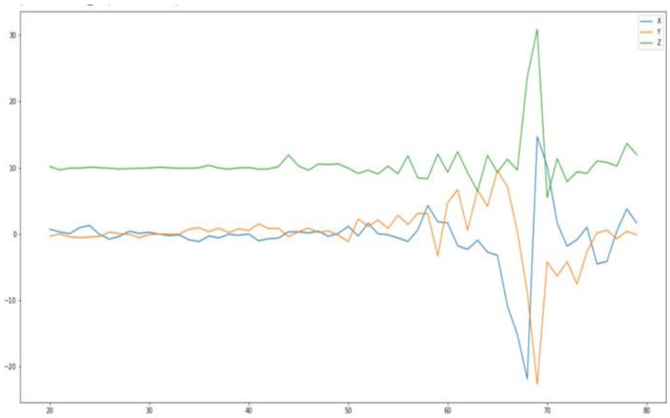

Fig-12c: Sample Data 3

The samples were collected to understand the behavior under different states. After data wrangling, the data was then fed to the ML model to make predictions. An accuracy value of 91.8% was successfully achieved.

5. CONCLUSIONS

The prototype was successfully implemented and was confirmed to be giving accurate results concerning the primary functions viz. student detection using RFID, intrusion detection, location tracking and accident detection. The secondary functions viz. attendance analysis, route estimation, cloud-storage of required data and custom alarms was verified to be working as desired too.

The prototype has advantages over GSM and Arduino based systems as it couples GPS with Google maps APIs to provide us the live location and real-time tracking of children.

All in all, this was a successful step for smarter future for Smart School buses.

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