JOURNAL OF MECHANICS OF CONTINUA AND MATHEMATICAL SCIENCES
www.journalimcms.org

ISSN (Online) : 2454 -7190 Vol.-21, No.-05, May (2026) pp 74-90 ISSN (Print) 0973-8975

ADITYA ROUTE ROVER: A LOW-COST AND EFFICIENT IOT-BASED BUS MONITORING SYSTEM

Venkata Lalitha Narla[1], R. V. V. Krishna[2], Peruri Pavani[3], MD. Abdul Azeez Khan[4], A. Sravanthi Peddinti[5]

[1,2,5] Department of Electronics and Communication Engineering, Aditya University, Surampalem, A.P., India.

[3,4] Department of ECE, Aditya College of Engineering & Technology, Surampalem, A. P., India.

Email: [1]lalithanarla.ece@gmail.com

Corresponding Author email: **Venkata Lalitha Narla**

https://doi.org/10.26782/jmcms.2026.05.00006

(Received: February 22, 2026; Revised: May 04, 2026; Accepted : May 12, 2026)

Abstract

Aditya Route Rover: Low-Cost and Efficient Bus Monitoring System is an integrated system that offers real-time monitoring of college buses with emphasis on the safety of the students and the efficiency of the buses. The proposed system is a combination of GPS technology and face recognition, which is used to continually monitor the position of the bus and students on board. Processing of captured digital images and video frames is used to extract facial features for real-time student recognition. The GPS module can be relied on to give the correct location of the students, and the face recognition module will help to monitor students securely and reliably. An onboard controller processes the collected information from the sensors and communicates to a central server, where it is accessed and managed in real-time. The system increases transparency in the transportation of college students for safety, and it offers reassurance to parents. The proposed system can be deployed in academic transportation because of its low-cost structure and scalable architecture.

Keywords: GPS module, Face Recognition, Raspberry Pi, Real-time monitoring, College Bus, Smart Transportation.

I. Introduction

Transport systems are crucial to enduring the everyday travelling process, especially in learning institutions where the security and time-consciousness of the transportation of students are of major concern. As urbanisation offers immense growth, people become more reliant on transport provided by the state and private services alike. There is a huge demand for smart systems that will offer real-time tracking, transparency of operation, and greater safety. It is against this backdrop that smart bus tracking and monitoring systems have been developed as a solution to enhance the efficiency and user confidence in transportation [XVIII].

The Aditya Route Rover is an intelligent bus-tracking and monitoring system developed to make transportation more efficient and safer at the college level. The proposed system is developed on Raspberry Pi as the main controller with a camera module, a display unit, and database support for real-time bus and student monitoring. With a user authentication web-based interface, administrators and authorised users can access bus locations, schedules, and monitoring information easily. The system is a reliable platform for current academic transport management by integrating real-time tracking and biometric identification.

In the past few years, facial recognition technology has received considerable attention with the development of artificial intelligence, computer vision, and embedded systems. Facial recognition is a biometric way of authentication, used to identify a person, analysing distinctive facial features through images or video streams. Facial recognition is now used extensively, even though its accuracy is relatively low compared to the iris or fingerprint recognition, because it is non-invasive, contactless, and user-friendly. These benefits have seen it be used in large numbers in the applications of access control systems, video surveillance, human-computer interaction, and smart city systems, [XVI, V].

Work II has proved the efficiency of face recognition systems in real-time, utilising lightweight convolutional neural networks and embedded hardware platforms. These systems support the proper identification of persons without the need for any physical interaction, making them applicable in public transportation services, as well as in the student monitoring system. Facial recognition is also applied to transport systems, making it even more secure because only authorised people are recognised and tracked during transportation.

Another important element of intelligent transportation is real-time tracking systems. These systems facilitate continuous surveillance of vehicles, assets, or individuals by gathering information regarding location and movement. With the combination of sensors, communication systems, wireless networks, and centralised data processing systems, real-time tracking systems enable the delivery of actionable insights for effective decision-making and situational awareness [XIX, XXI, VII]. Real-time tracking is beneficial in transportation, as it helps to improve route management, minimise delays, and increase passenger confidence.

Various works have emphasised the advantages of GPS-enabled tracking systems along with IoT designs for real-time tracking of vehicles and visualisation of data [X, XVI]. But existing studies mainly focused on vehicle-level tracking and the dissemination of passenger information, with limited attention on individual-level tracking and safety monitoring. This limitation motivates the development of a new integrated system that would bring together real-time tracking and biometric identification.

Aditya Route Rover addresses this limitation by combining GPS-based bus tracking and face recognition-based student tracking into a low-cost system. The bus tracking system monitors the bus position continuously and, at the same time, detects students on the bus and sends the processed data to a central server to be accessed in real-time. It is a viable solution for academic transportation systems since this single procedure enhances the safety of students, the efficiency of operation, and provides parents and administrators with reassurance.

II. Literature Survey:

The initial studies carried out in the field of monitoring of public transportation were mainly concerned with GPS vehicle tracking systems to enhance control of the work and the information supplied to the passengers. In 2014, a few researchers recommended bus tracking systems with the help of GPS transceivers, SMS, and web-based applications created on PHP, MySQL, and WAMP server framework, and applied them to track the real-time position and the schedule of the buses [XIII]. These systems enhanced the view of planned and operational buses, though this was limited to vehicle-level features without passenger tracking and safety features. The later developments carried on with the GPS-based tracking technique to include Google Maps, GPRS, and mobile applications to offer real-time location updates, estimated arrival times, and local bus stop data to improve the convenience of passengers and minimise waiting hours [IV].

As Internet of Things (IoT) technology has developed, researchers have started to use sensor-based and cloud-related architectures in public transport monitoring. The IoT-based systems were based on nodeMCU, ESP8266, and ESP32 microcontrollers using GPS, GSM/GPRS that relayed real-time information about the vehicles like their location, speed, and route to the centralised servers [XVII, XV]. These systems offered web and mobile interfaces, which enabled the passengers and administrators to track the movements and arrival of the bus in real time. Others have used RFID technology by placing tags on buses and readers at bus stops to identify the presence of the bus and send data to cloud servers, which are less expensive than constant monitoring by GPS VIII. Nevertheless, these infrastructure-based solutions only offered stop-level tracking and lacked onboard monitoring.

Similar studies investigated the use of passenger-oriented monitoring and counting systems to enhance the efficiency of service planning and safety. Video sensing, floor sensors, WiFi, and infrared-based Automatic Passenger Counting (APC) technologies were tested under realistic working conditions and found to have trade-offs in terms of accuracy, costs, and complexity of deployment [XIV]. Although some of the strategies attained reasonable accuracy rates, all of them had a strong dependence on the trip length and service frequency. Other research dealt with the safety of children by combining IoT with RFID-based identification protocols to monitor students in schools on school buses, to provide real-time data on their location, and create reports which can be accessed by parents and administrators [IX]. These systems relied on card-based identification, which can be abused and cannot guarantee the real identification of individuals.

Recent research has increasingly leveraged computer vision and embedded systems to enhance transportation monitoring efficiency. Vision-based traffic monitoring systems contain Raspberry Pi and camera modules employed OpenCV and Python to identify, track, and estimate vehicles in heavy traffic situations, which provides low-cost alternatives to traffic management [XI]. State-of-the-art vision-based pipelines also offered CNN-based vehicle detection networks with real-time tracking algorithms like SORT to accurately predict vehicle speed, whose main aim was to identify a violation of speed and surveillance in traffic I. These methods were effective but were focused on vehicle-level monitoring rather than Passenger-level identification.

Advances in the management of public transport also focused on system architectures, communication protocols, and other alternative sensing technologies. A literature review on the IoT communication standard has revealed that bandwidth efficiency, latency, power consumption, and secure data transmission are the key factors in ensuring an efficient transport monitoring system [XX]. Other methods, like the use of Bluetooth Low Energy (BLE) proximity sensing, were suggested to overcome GPS drawbacks in developing regions and provided successful stop-level detection and arrival time estimation during field testing [XVI]. They also adopted web-based systems with a built-in Google Maps and QR code scanning to increase access to the real-time routes of buses, timetables, and drivers' information, which provided users with significant benefits, but was limited to the dissemination of information III.

Later, IoT-based solutions focused not only on tracking the location but also on monitoring the vehicle parameters of occupancy, fuel consumption, temperature, and humidity, especially in logistics and dedicated transport environments VI. Such systems demonstrated the potential of using multi-sensor IoT systems to enhance operational efficiency and cost control. The lightweight and low cost of object detectors and trackers also demonstrated that real-time computer vision could be feasible on embedded platforms at meter-level geolocation accuracy, but were mostly limited to aerial or environmental surveillance [XII].

Overall, the reviewed literature reveals that, currently, the focus of available systems for monitoring the transport sector is at the vehicle level, with services for monitoring the people in transit, traffic observation, or infrastructure-based identification shown in Table 1. Limited attention has been provided to low-cost integrated systems that include real-time GPS monitoring with passive vision identification and tracking of passengers. This research gap motivated the proposed Aditya Route Rover, which will improve the safety of the students, operational efficiency, and parental assurance by incorporating GPS-based bus tracking and face recognition-based student tracking in a single and scalable system.

Table 1: Summarized Literature Survey of State-of-the-art works.

Ref.	Technology Used	Application Focus	Key Features	Limitations
2014, XIII	GPS, SMS, PHP, MySQL	Bus tracking	Real-time location via SMS	No passenger monitoring
2014, IV	GPS, GPRS, Google Maps	Passenger information	Live bus location, ETA	No safety or identification
2020, XI	Raspberry Pi, OpenCV	Traffic monitoring	Vehicle detection & counting	Not public transport focused
2021, XIV	Video, IR, WiFi, Floor sensors	Passenger counting	Occupancy estimation	Accuracy varies with routes
2021, IX	IoT, RFID, Cloud	Child safety	Student tracking, reports	RFID misuse possible
2021, VIII	RFID, NodeMCU, Cloud	Bus status tracking	Real-time bus detection	Stop-level tracking only
2021, XVII	GPS, ESP32, IoT	Bus arrival prediction	Distance & ETA estimation	No passenger verification

2023, I	CNN, SORT, Vision	Speed monitoring	High accuracy (87.2%)	Traffic-only application
2023, XX	IoT protocols, Cloud	Transport data management	Secure IoT architecture	Conceptual, no deployment
2023, XVI	BLE, Raspberry Pi	Fleet tracking	GPS alternative, low-cost	No continuous tracking
2023, III	Web app, Google Maps, QR	Route information	Live routes & driver info	No onboard monitoring
2024, XV	GPS, GSM, NodeMCU	Bus tracking	Location, speed, occupancy	No identity recognition
2024, VI	IoT sensors	Vehicle monitoring	Fuel, temp, humidity	Logistics-focused
2024, XII	Embedded vision, GPS	Object tracking	Meter-level accuracy	Not transport-specific

Main Contributions:

- This work proposes a cost-effective bus tracking system that integrates via a GPS module with face recognition to identify students.
- The system enhances the level of safety of students because it constantly shows the presence of students in the bus and prevents unauthorised access.
- An IoT-based architecture is employed to transmit real-time data about bus locations and students to a central server for easy monitoring.
- The system proposed is easy, expandable, and can be used in transportation systems in colleges.

III. Methodology and Design:

Aditya Route Rover system, shown in Fig. 1, is designed with the agile methodology supporting flexibility, iterative development, and constant improvement during the project lifecycle. Traditional bus monitoring systems mostly used IR sensors or simple microcontroller platforms to monitor buses. The proposed system combines various interconnected hardware and software subsystems to provide real-time bus tracking and monitoring.

All buses have a GPS module that constantly records the real-time position of the bus and passes the information to a centralised control unit. The control system interacts with a central database, where bus location and operation information will be provided and updated dynamically, which ensures the accurate availability of the data. The user control system is a system that is usually installed on the server or the computer and that processes incoming user requests and pulls real-time location data from the database. This information is available in a web-based application, which allows users to monitor buses, request details, and get updates easily. The synchronised interaction between the GPS module and database, the control system, and the user interface ensures effective communication and transportation monitoring.

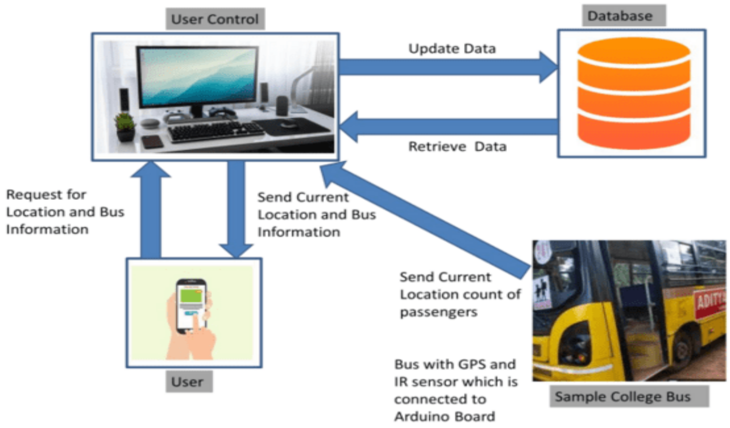

Fig. 1. Working of the Bus Monitoring System

The architecture of the system integrates several essential elements to offer real-time tracking in a smooth way. The GPS module, which is mounted on each bus, serves as the major source of the data because it constantly monitors the location of the bus. This information flows over the network to the central database, which serves as the storage and management hub for real-time location updates and other operational parameters. The database enables efficient data retrieval and updating, which allows users to access accurate and timely information. The flow of data between the system and the user interface remains consistent all the time by maintaining a smooth flow of data between the GPS module, the database, and the user interface.

The user control system acts as the point of communication between the buses and the database. It takes care of user queries and requests, and provides the necessary information, like live bus position in real-time. The system is accessed by users with the help of a web application that enables users to access bus information and live tracking. A well-defined communication interface facilitates effective communication amongst different components of the system. The availability of reliable network connectivity will guarantee the continuity of data transmission between the GPS devices, server, database, and user devices, leading to a reliable real-time bus tracking solution.

Agile development is based on an iterative and incremental design, whereby the main functions of real-time GPS positioning, user authentication, and data management are developed and enhanced throughout the small development cycles as depicted in Fig. 2. In the case of Aditya Route Rover, this can be used to quickly respond to changes and integrate user feedback to enhance the accuracy of tracking and the overall system's performance. The project will be split into small parts so that hardware components can be integrated consistently, including the Raspberry Pi microcontroller, GPS modules, and camera, the software part, including MongoDB as a data storage system, and the user-friendly web interface. The introduction plan contributes to the flexibility, efficiency, and reliability of the system.

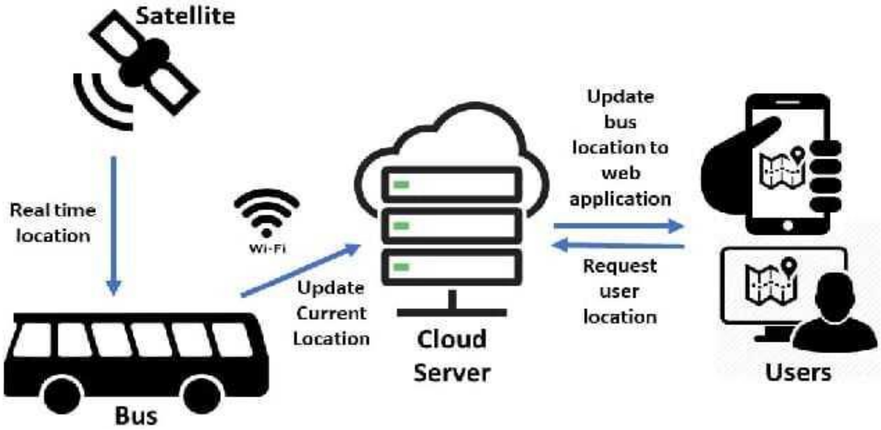

Fig. 2. System Overview of Bus Monitoring System

During the analysis phase, key system components and functional requirements are identified to ensure effective operation. Raspberry Pi is chosen as the main processing unit, the GPS unit is used to track the location, the camera unit is engaged in facial recognition, MongoDB is involved in data storage, and the web interface gives a user access. There is a special concern for real-time information processing, secure authentication of users, and accuracy of tracking to provide an efficient system integration and reliable performance.

During the design stage, the system architecture can be designed in such a manner that it is scalable, modular, and performance-oriented. It is based on a modular design philosophy whereby hardware and software components can communicate via a clearly defined API to support future upgrades and enhancements. The MongoDB database model is developed in a way that it will be convenient to store bus tracks, time, and user activity records. The interface is maintained to be easy and user-friendly so that the user can access information about real-time tracking easily. Also, the selection of the corresponding network communication protocols is carried out to guarantee the stable transmission of data between the Raspberry Pi and the web server, which adds to the overall system strength.

III.i. Face Recognition and GPS Tracking Algorithm:

The Face Recognition and GPS Tracking system is combined to enable real-time face recognition and continuous location tracking of individuals to provide better security and operational awareness. The system recognises individuals by capturing their facial images using a camera and extracting characteristic facial features, which are then compared with pre-stored facial encodings in the database. Along with feature matching, there is also a mechanism for real-time liveness verification to ensure that the identified face is not a spoofed input. This is done by examining over-time facial attributes, including eye-blink sequences, and natural differences between successive frames. The authentication decision is determined when both feature matching and liveness conditions are met, thus enhancing resistance against presentation attacks like printed images or replayed videos.

At the same time, a GPS module obtains real-time location information in terms of latitude and longitude positions. Raw GPS measurements are usually subject to environmental noise, which can cause fluctuations in the reported position. A simple state estimation method is then taken to enhance the accuracy of the tracking, and in this method, the current position will be estimated using the previous state and the motion dynamics. The system is modelled as follows: The location of the bus at time t is described as:

$$x_t = x_{t-1} + v_t \Delta t + w_t \quad (1)$$

x_t = the actual position, v_t = the velocity, Δt = the time interval, and w_t = process noise. The GPS reading that is observed is provided by:

$$z_t = x_t + n_t \quad (2)$$

z_t measured position and nt measurement noise. To smooth out the position estimate, a correction process is performed as follows:

$$\hat{x}_t = \hat{x}_{t-1} + K(z_t - \hat{x}_{t-1}) \quad (3)$$

where $\hat{x}_t$ is the predicted position, and K is a gain factor that trades the effect of the predicted and measured positions. The noise reduction and averaging of varying trajectories, as well as more stable and reliable location tracking, are seen to be the products of this filtering process.

The processes of facial recognition and GPS tracking are implemented in parallel with multithreading to ensure the achievement of real-time performance. The system architecture guarantees that the video frame processing and GPS data acquisition processes can run simultaneously without a significant lag. This parallel processing allows efficient processing of continuous video streams and periodic location updates, so that data is transmitted to the server in time and the movement of both the passengers and vehicles is accurately monitored.

Algorithm 1: Face Recognition and GPS Tracking System

Input: Video stream V, GPS data stream G, Face database D
Output: Authenticated user identity and filtered GPS location

1: Initialize camera, GPS module, and API endpoints
2: Load face encodings from database D
3: Initialize state estimate $\hat{x}_0$ and previous state $\hat{x}_{t-1}$
4: Set time interval Δt and gain factor K
5: Start parallel threads:

Thread 1: Face Recognition

6: while the system is active, do
7: Capture frame from video stream V
8: Detect faces in the frame
9: Extract facial features (encoding E)
10: Compare E with database D
11: if match found then
12: Perform liveness verification L(I)

```
13:       if L(I) == TRUE then
14:           Authenticate user
15:           Send identity data to the server
16:       else
17:           Reject as a spoof attempt
18:       end if
19:   end if

20:   Display bounding box and identity
21: end while

-------------------------------
Thread 2: GPS Tracking
-------------------------------
22: while the system is active, do
23:     Read GPS data (latitude, longitude)
24:     Convert GPS data to position zt

     // Prediction step
25:     x_t = x_t-1 + v_t * Δt

     // Measurement update
26:     z_t = x_t + noise

     // Correction step
27:     x̂_t = x̂_t-1 + K * (z_t - x̂_t-1)

28:     Update state: x̂_t-1 ← x̂_t
29:     Send filtered position x̂_t to server
30: end while
-------------------------------
31: On termination:
32:     Release camera and GPS resources
33:     Close all processes
```

III.ii. Back-End and Front-End Processes:

As shown in Fig. 3, the proposed bus monitoring system has two major functional modules that are identified as crowd-based face recognition and GPS-based bus tracking as the backend process. The crowd face detection system starts with a live video feed, which is taken by a camera fitted inside the bus. This video feed is analysed with face detection and recognition algorithms to recognise passengers and derive their facial features. The identified facial information is further used to approximate the occupancy rates so that the real-time people density and movement in the bus can be monitored. This data can help the administrators to realize passenger flow and enhance the effectiveness of the work.

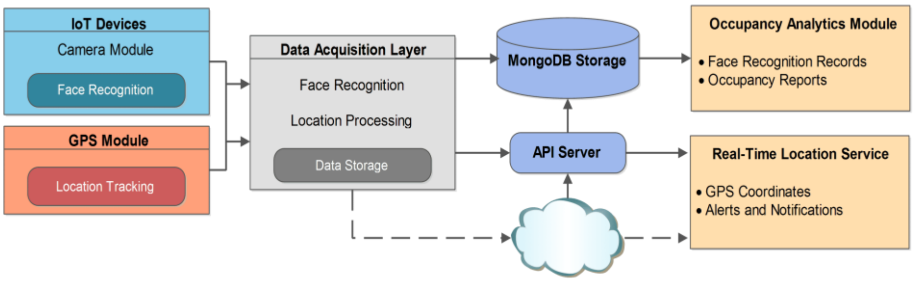

Fig. 3. Backend Process

At the same time, the GPS tracking module continuously acquires real-time location and speed information from the GPS sensor attached to the bus. Raw GPS information is read and run through processing software so that it can calculate the correct latitude and longitude and speed, which are then transmitted to the backend server. With a combination of facial recognition results and GPS-based location information, the system can facilitate complete control of the buses, proper tracking of their routes, and improved safety control. The automated backend structure is efficient in handling data, maintaining a trustworthy communication between the database, and continuous real-time updates, thereby enhancing the robustness and scalability of the transportation monitoring system.

The front-end process of the system, as shown in Fig. 4, is intended to display real-time information with an interactive web-based interface. The application has a map-based visualisation that enables the user to monitor the real-time position of buses on fixed routes. The front-end is constantly connected with the backend server to show the latest GPS coordinates and approximate arrival times.

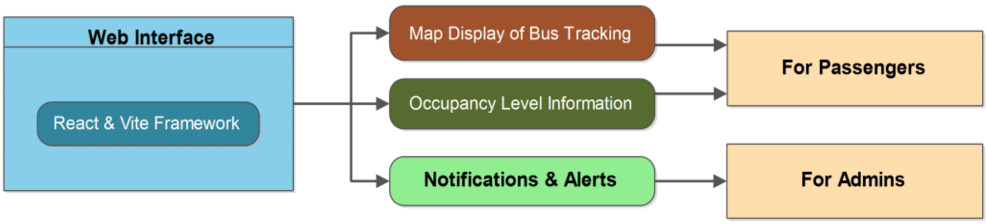

Fig. 4. Front-end Process

To increase usability, the system creates notifications and alerts associated with the arrival of the buses, their delay, and occupation. This is very important as it saves time on passengers waiting, as well as enhancing total commuting efficiency. The fluidity of the interface between the back-end data processing components and the front-end visualisation interface will guarantee the proper and timely transmission of accurate and reliable information to the end users.

Generally, Aditya Route Rover is a low-cost and effective bus-tracking technology, which combines GPS tracking, face recognition, and real-time data processing as a way of enhancing the management of public transport. The system will be designed using the Raspberry Pi 4, a GPS unit, and a USB camera to provide accurate location tracking and increase the safety of the passengers with the help of biometric identification. The backend architecture guarantees efficiency in data processing and database interaction, and the front-end web interface allows obtaining live tracking, alerts, and information about a passenger easily. The combination of smart sensing, a network, and real-time analytics leads to the maximization of urban mobility and makes the commuting experience better.

IV. Results and Discussion:

The performance analysis of the Aditya Route Rover is on the efficiency of the real-time bus tracking, face recognition, and web-based monitoring features. It is possible to consider that the developed system shows a good level of GPS-based tracking and face recognition algorithm integration to enhance the fleet management system, passenger safety, and transparency of operations. The findings are described using interface screenshots and system outputs and emphasise the practical applicability and effectiveness of the proposed solution.

Fig. 5 shows the login page of the web application called Aditya Route Rover. The interface is built with a lean and sparse design and enables users to get into the system with their credentials. The main idea of the platform is embodied in the tagline, which is *"Track, Manage, Simplify*". The color system and structure contribute to the increased readability and user-friendliness, and the presence of contact details and social networking enhances the accessibility and reachability of the system.

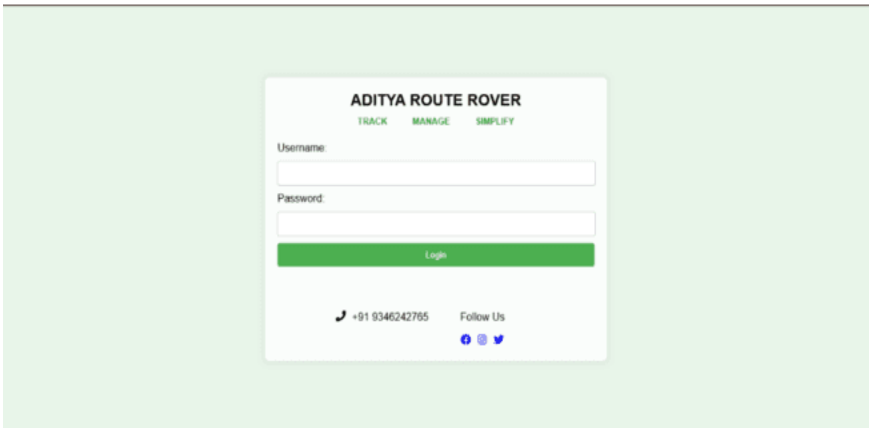

Fig. 5. Login Page

After successful authentication, the user will be redirected to the Student Dashboard, as in Fig. 6. This dashboard gives customised student data and transportation information. In the left panel, personal information, including photograph, roll number, department, campus, and academic year, is provided, whereas in the right-hand side, bus-related information, including bus number, driver information, registration number, route, and operational status, is displayed. A live map embedded in the dashboard will allow tracking the assigned bus in real-time, and students can plan their travel means. More user control features, like *Start Journey* and *Logout,* also make the system easy to use.

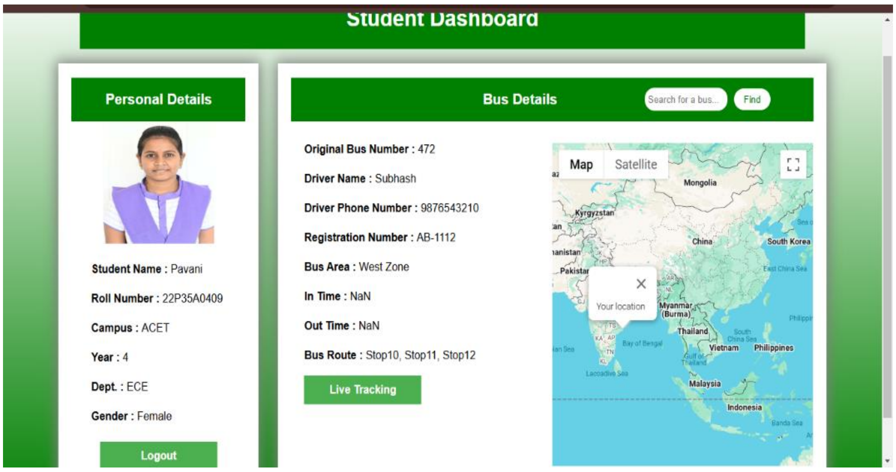

Fig. 6. Student Dashboard

The route visualisation option is presented in Fig. 7, in which the route followed by the bus is displayed on the map as a continuous line of blue color. The pathway consists of the major landmarks in the Aditya University campus, which include academic blocks, the library, and the canteens. Marked start points and end points will enable users to track the progress of their journey in real time, which will enhance navigation awareness and transparency during travel.

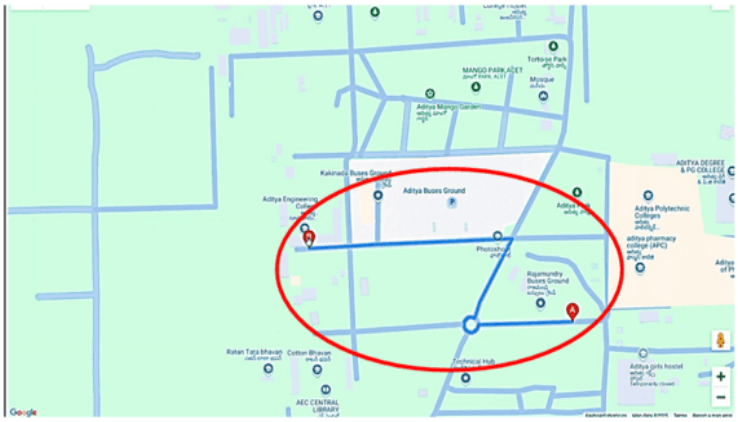

Fig. 7. Map View

The system administrative functions are shown in Fig. 8, which is a web-based management dashboard created based on React and Vite. The sidebar menu gives access to student, employee, and bus management modules. The primary panel presents tabular records of employee data, such as identification and institutional affiliation. There are action buttons to edit and remove records to enable effective data management. The interface design will focus on being straightforward, user-friendly, and effective for administration with MongoDB as the back-end database, allowing storage of data in a secure and scalable manner.

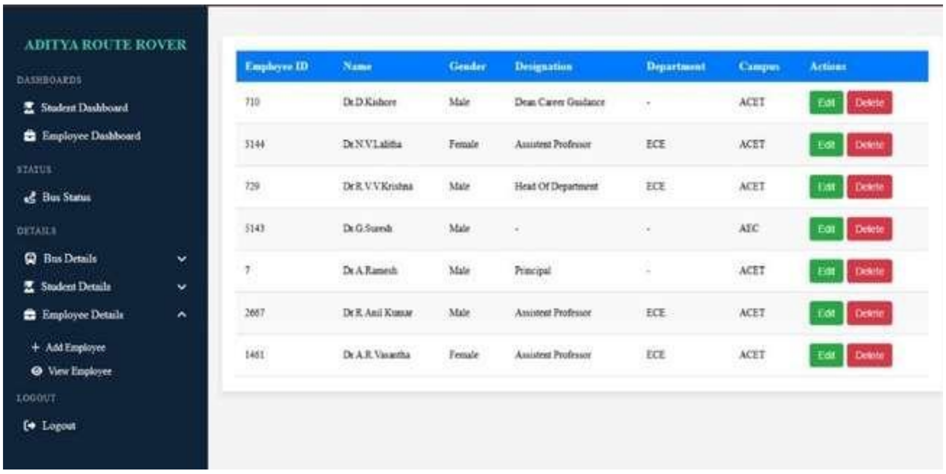

Fig. 8. Employee Details

Fig. 9 represents the student registration module where administrators add new student records together with facial images. The form contains vital information like roll number, name, department, campus, academic year, and bus assigned. Image upload functionality is also included, which allows the use of facial recognition to identify the person, reinforce the security level, and allow monitoring passengers automatically. The data entry is precise and efficient as the form is organised and designed to be user-friendly.

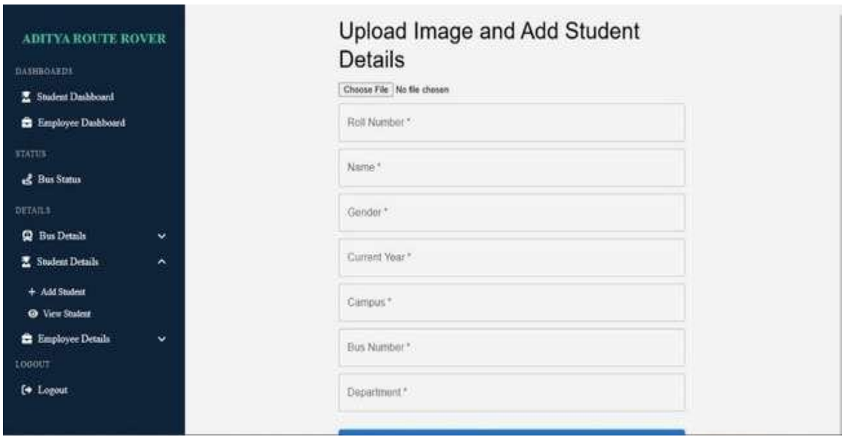

Fig. 9. Format of Student Details

The bus management interface is shown in Fig. 10. This interfaces the administrators to monitor and control bus-related information using a card-based layout. The cards contain important information like bus number, driver name, contacts, and operational area. Searching and structured design allow rapid access to the transportation data, which enhances the responsiveness of the system and its management.

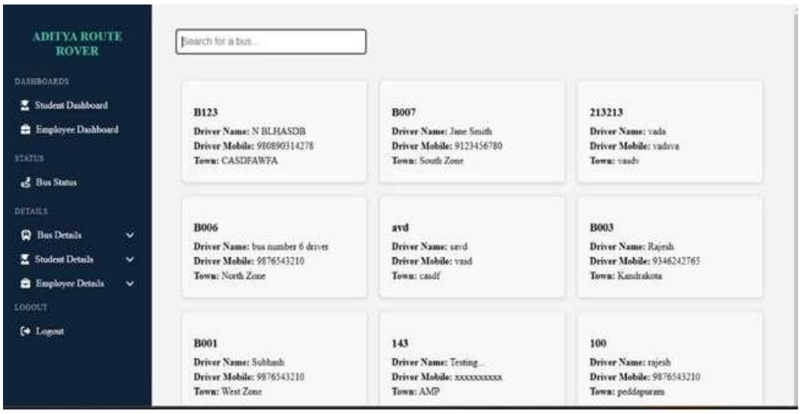

Fig. 10. Bus Details

Fig. 11 illustrates the hardware implementation of the face recognition module with the help of a Raspberry Pi with a camera and touchscreen display. The system is effective for the identification and detection of individuals matching live facial images to encodings stored in the system. Bounding boxes are used to highlight recognised faces, and roll numbers are displayed, which ensures that real-time identification happens correctly. The module is very important in passenger authentication and attendance tracking in buses.

Fig. 11. Face Recognition Window

Finally, Fig. 12 shows the face recognition and GPS tracking script to be executed in the Visual Studio environment. The Python version of the instruction incorporates OpenCV, face recognition, and a serial communication library. The terminal output indicates that real-time GPS coordinates have been acquired and sent successfully, which justifies the system as being able to process facial data and location information simultaneously.

Fig. 12. GPS Location Coordinates

Overall, the experimental findings confirm that the Aditya Route Rover provides a cost-effective, dependable, and efficient solution for real-time bus tracking. The smooth assimilation of the hardware and software modules provides reliable tracking, greater passenger security, and better operational management of transportation, as well as qualifies the deployment of the systems to learning institutions and smart campuses.

V. Conclusion

The project Aditya Route Rover offers a cost-effective and efficient bus tracking system that combines facial recognition with GPS real-time tracking to enhance transportation management within institutions of learning. The facial recognition system installed on Raspberry Pi and OpenCV allows identifying students with high accuracy and security, helping to get rid of manual attendance and improve the safety of the passengers. The GPS tracking module enables real-time and accurate live updates of location so that the students, parents, and administrators can be able to follow the progress and whereabouts of the bus and bus routes in real-time. The web dashboard created in React and Vite will provide a centralised database with access to the student information, employee records, and bus locations, making it easy to use and efficient to work with. All in all, this system proves to be an efficient, expansive, and user-friendly solution for smart campus transportation.

Incorporating AI-based route optimisation and the prediction of arrival time, based on historical traffic and real-time traffic data, will improve the system. The use of deep learning models and liveness detection methods can enhance face recognition accuracy. Also, scalability and access can be enhanced further with the assistance of cloud deployment and mobile applications.

VI. Acknowledgment:

The authors thankfully acknowledge the financial support provided by The Institute of Engineers (India) for carrying out Research & Development work in this subject.

Conflict of Interest:

The authors declare that there was no relevant conflict of interest regarding this paper.

References

I. Ashraf, Muhammad Hassaan, et al. "HVD-Net: A Hybrid Vehicle Detection Network for Vision-Based Vehicle Tracking and Speed Estimation." *Journal of King Saud University - Computer and Information Sciences*, vol. 35, no. 8, The Authors, 2023, pp. 1–19, 10.1016/j.jksuci.2023.101657.

II. Atzori, Luigi, et al. "The Internet of Things: A Survey." *Computer Networks*, vol. 54, no. 15, 2010, pp. 2787–805.

III. Balani, Zina, and Mohammed Nasseh Mohammed. "Web-Based Bus Tracking System in the Internet of Things IoT." *International Journal of Science and Business*, vol. 28, no. 1, 2023, pp. 31–40, 10.58970/ijsb.2203.

IV. Bharte, V., et al. "Bus Monitoring System Using Polyline Algorithm." *International Journal of Scientific and Research Publications*, vol. 4, no. 4, 2014, pp. 1–4, http://www.ijsrp.org/research-paper-0414/ijsrp-p2829.pdf.

V. Botta, Alessio, et al. "Integration of Cloud Computing and Internet of Things: A Survey." *Future Generation Computer Systems*, vol. 56, 2016, pp. 684–700.

VI. Huynh, Nguyen Bao Phuong, and Duy Thong Nguyen. "Implementation of an IoT-Based System for Monitoring Parameters and Tracking Transport Vehicles." *Journal of Technical Education Science*, vol. 19, no. 06, 2024, pp. 66–74.

VII. Jain, A. K., et al. "An Introduction to Biometric Recognition." *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 14, no. 1, 2004, pp. 4–20.

VIII. Jain, Anjali, and Dr. Agya Mishra. "Design of IoT Based Real-Time Bus Tracking App Using HF-RFID." *The International Journal of Recent Technology and Engineering (IJRTE)*, vol. 9, no. 6, 2021, pp. 71–75, 10.35940/ijrte.f5365.039621.

IX. Jeyakkannan, N., et al. "IoT Based Smart Bus System Using Wireless Sensor Networks." *Journal of Physics: Conference Series*, vol. 1937, no. 1, 2021, pp. 1–9. 10.1088/1742-6596/1937/1/012017.

X. Krishnan, R. Santhana, et al. "Secured College Bus Management System Using IoT for Covid-19 Pandemic Situation." *Proceedings of the 3rd International Conference on Intelligent Communication Technologies and Virtual Mobile Networks, ICICV 2021*, 2021, pp. 376–82. 10.1109/ICICV50876.2021.9388378.

XI. Kulkarni, Apeksha P., and Vishwanath P. Baligar. "Real Time Vehicle Detection, Tracking and Counting Using Raspberry-Pi." *2nd International Conference on Innovative Mechanisms for Industry Applications, ICIMIA 2020 - Conference Proceedings*, no. Icimia, 2020, pp. 603–07. 10.1109/ICIMIA48430.2020.9074944.

XII. Lago, Allan, et al. "Low-Cost Real-Time Aerial Object Detection and GPS Location Tracking Pipeline." *ISPRS Open Journal of Photogrammetry and Remote Sensing*, vol. 13, no. May, Elsevier B.V., 2024, pp. 1–8. 10.1016/j.ophoto.2024.100069.

XIII. Maruthi, R., and C. Jayakumari. "SMS Based Bus Tracking System Using Open Source Technologies." *International Journal of Computer Applications*, vol. 86, no. 9, 2014, pp. 44–46. 10.5120/15017-3305.

XIV. McCarthy, Chris, et al. "A Field Study of Internet of Things-Based Solutions for Automatic Passenger Counting." *IEEE Open Journal of Intelligent Transportation Systems*, vol. 2, no. January, IEEE, 2021, pp. 384–401. 10.1109/OJITS.2021.3111052.

XV. Nirmala, M., et al. "Bus Tracking System With IoT Integration." *International Journal of Emerging Knowledge Studies*, vol. 03, no. 08, 2024, pp. 438–42. 10.70333/ijeks-03-07-028.

XVI. S, Srinivas, et al. "Iot Based School Bus Monitoring System." *International Journal for Research in Applied Science & Engineering Technology*, vol. 11, no. V, 2023, pp. 394–400. 10.1109/ICDI3C61568.2023.00021.

XVII. Salih, Thair A., and Noor K. Younis. "Designing an Intelligent Real-Time Public Transportation Monitoring System Based on IoT." *Open Access Library Journal*, vol. 08, no. 10, 2021, pp. 1–14. 10.4236/oalib.1107985.

XVIII. Singla, Leeza, and Parteek Bhatia. "GPS Based Bus Tracking System." *2015 International Conference on Computer, Communication and Control (IC4), Indore, India*, 2015, pp. 1–6.

XIX. Totawar, Aniket, et al. "IOT Monitoring Smart School Bus." *International Journal for Research in Applied Science & Engineering Technology*, vol. 11, no. V, 2023, pp. 5984–87.

XX. V.V., Patil, et al. "IoT Based Intelligent Transportation System (IoT- ITS) for Global Perspective: A Case Study." *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, vol. 3, no. 6, 2023, pp. 250–56, doi:10.48175/568.

XXI. ZHAO, W., et al. "Face Recognition : A Literature Survey." *ACM Computing Surveys*, vol. 35, no. 4, 2003, pp. 399–458. 10.1145/954339.954342.