

Smart Campus Transit System Using Real-Time Face Recognition and Flask-Based Automated Access Monitoring

Dr. A. Radhika¹, P. Durga Harshini², SK. Payal Saniya³, K. Titus⁴, K.V.V. S. Vishnu Vardhan⁵

¹Professor, Dept. of CSE, SRK Institute of Technology, Vijayawada, Andhra Pradesh, India

^{2,3,4,5} UG-Scholars, Dept. of CSE, SRK Institute of Technology, Vijayawada, Andhra Pradesh, India

Emails: radhikaankala@gmail.com¹, peddapalliharshi31@gmail.com², skmohammedpayalsaniya@gmail.com³, k.titus150@gmail.com⁴, kvvs.vishnuvardhan@gmail.com⁵

Abstract

The Integrated Smart Campus Bus Management System (ISC-BMS) has been developed to provide a comprehensive and effective approach to managing transportation operations through the use of intelligent automation and real time monitoring. The various functional modules are combined into one system including driver log-in based attendance; Student Bus Pass Application Workflows, and Centralized Oversight Administrator Dashboard. It is proposed that using a face recognition subsystem will automate the process of taking attendance as students board the buses thereby improving accuracy in seating arrangements, reducing the opportunity for proxies, and increasing overall safety and security on campus. Real-time GPS location tracking will provide constant visibility of bus routes, as well as notification of the movement of the bus, delays, and whether the student is on board or not to parents. Several key limitations are addressed by the proposed framework including the limitations of current systems that only track or schedule services separately without incorporating any behavioral verification or automating identity authentication process(es). By integrating the above with biometric recognition, digital pass processing, and multi-role communication capabilities all into a single platform; school districts will be able to improve the safety, operational transparency, and user experience of their transportation operations thereby creating a more reliable and sustainable campus transportation management system.

Keywords: Smart Campus, Face Recognition, OpenCV, Flask, Histogram Features, CLAHE, Haar Cascade, Real-Time Authentication, Biometric System, Transit Monitoring.

1. Introduction

The goal of the Smart Campus Bus Management System will promote safety, efficiency and transparency in university transport services by introducing new technologies, intelligent automation and live connectivity with real-time data. Traditional university transport systems are operated manually via paper-based attendance and passes with limited communication tools. This results in transport service downtime, inaccuracies (in terms of how many students use the service verses what is recorded), and poor situational awareness of the status of the transport services. Using latest technology, the Smart Campus Bus Management System aims to provide students, drivers, administrators and parents with a large degree of confidence, security and reliability in their respective transportation systems. In achieving

these goals, the Smart Campus Bus Management System will automate student registration using facial recognition, digitize the process of registering and validating bus passes, allow driver login-based attendance, and create a central monitoring platform controlled by an administrator. The Smart Campus Bus Management System will also provide parents with GPS-based live tracking information of buses on campus and notify parents through electronic push notifications (or text messages) to allow for real-time communication, which builds trust in the campus transport operation. Together, these combined objectives will create a higher level of process transparency and operational accountability. This architecture combines many modules into one system: A facial recognition biometric attendance

engine; a mobile/web interface that can be used to apply for a digital pass; a driver attendance and authentication subsystem; and an admin dashboard to oversee the transportation routes, the fleet of buses, and records of the students who use this type of transportation service. It allows for visualization of movement in real time, as well as automatic notifications to parents when buses leave, arrive, and when students board. Using this multi-layered framework, the transportation management system provides an end-to-end solution that addresses the long-standing problems of transporting students via traditional manual and semi-digital processes. The proposed transportation management system framework corresponds to a number of important United Nations Sustainable Development Goals (SDGs), including SDG 4: Quality Education by ensuring that students have safe and organized mobility; SDG 9: Industry, Innovation, and Infrastructure through the use of artificial intelligence, the Internet of things, and automation in transportation; SDG 11: Sustainable Cities and Communities by maximizing mobility and reducing inefficiencies in how transportation is delivered; and SDG 16: Peace, Justice, and Strong Institutions by increasing the level of accountability and transparency in campus transportation operations. All of these contributions make the proposed transportation management system framework a viable and innovative sustainable transportation management solution

2. Related Works

Borne et al. [1] investigated the implementation of electric buses in university transportation systems, emphasizing sustainable mobility and reduced carbon emissions. Their study demonstrated operational efficiency gains; however, it lacked integration of real-time driver behavior monitoring, limiting its applicability for enhancing road safety and driver accountability. Sulaiman et al. [2] developed OnBoard, a mobile application for real-time bus tracking within a university campus. While it enabled locational visibility and route monitoring, the system did not incorporate behavioral analytics or predictive risk assessment, constraining its utility for proactive safety management. Ibrahim et al. [3] proposed

CampusWay, a data-driven real-time bus booking system with dynamic allocation algorithms. The approach optimized vehicle allocation but did not evaluate driver performance metrics, leaving a gap in behavioral oversight. Rungskunroch et al. [4] conducted simulation-based optimization of university shuttle bus systems, focusing on route efficiency and energy utilization. Despite demonstrating energy and operational benefits, their study did not integrate sensor-based telemetric data or provide real-time interventions for unsafe driving behaviors. Deepak et al. [5] presented a minimal-IoT bus tracking website for universities, illustrating low-cost monitoring solutions. Nonetheless, the framework lacked longitudinal behavioral trend analysis and real-time alerting, limiting its capacity to instill sustained driver accountability. Aggarwal et al. [6] examined organizational innovation as a business strategy, offering bibliometric insights into institutional transformations. Although informative for strategic implementation, their work does not directly address transportation safety or driver monitoring systems. Shah et al. [7] explored challenges in digital dataset management within university libraries, highlighting governance and accessibility concerns. While technically relevant, the study does not contribute to vehicular telemetry or behavioral scoring methodologies. André [8] discussed pedagogical challenges for sustainability education, emphasizing behavioral modification and awareness. This work informs conceptual frameworks for driver training but lacks empirical deployment in transportation monitoring contexts. Roshid and Kankaanranta [9] investigated communication skill gaps in international business education. Although highlighting training interventions, it does not address real-time driver feedback or operational analytics. Talafidaryani et al. [10] traced the evolution of digitalization research in business and management using deep learning and bibliometric forecasting. The methodology offers analytical paradigms but remains untested in vehicular behavioral analytics or real-time monitoring frameworks. Yawson [11] provided leadership lessons from university administration, elucidating managerial decision-making and

accountability. While relevant for system governance, the work does not encompass sensor-based driver evaluation. Gazi et al. [12] examined entrepreneurship development in university students, highlighting behavioral and technological adaptability. The behavioral insights can inform training modules but do not provide real-time monitoring or alert systems for transport operators. Matas-Monroy et al. [13] conducted importance-performance analysis of public transport on campus, revealing user preferences and service gaps. While valuable for operational planning, the study lacks driver-centric behavioral evaluation. Opuwari and Uzoigwe [14] explored resource management education and self-employment intentions of graduates. Though relevant to behavioral studies, it does not address real-time driver safety or risk assessment.

3. Comparison with Previous Methodology

In the past, campus transportation or attendance tracking systems used manual verification, or were dependent upon RFID cards, QR codes, or basic image capture systems; which offered no automated authentication and no real time decision making. Because these manual processes were subject to delays and human error, proxy and/or unauthorized use was also a possibility. In contrast, although RFID and QR code systems have made the identification process faster, they still require students to carry a physical "token", which may be lost, damaged or inappropriately used. Additionally, many previous face detection systems used only raw image matching without enhancement techniques, producing very poor recognition rates with varying lighting, occlusion and/or camera quality. These limitations combined created several barriers limiting operational efficiencies and prevented the support of large scale, high frequency transit environments. The proposed methodology covers these limitations by using a combination of real-time face recognition, advanced preprocessing techniques, and a web-based management architecture. The system uses CLAHE based enhancement and histogram feature encoding to provide a more robust solution for face recognition under less than adequate visual conditions. Finally, the use of the Flask framework also provides

centralised control over registration, monitoring, and authorisation while eliminating the need for the use of physical credentials.

Table 1 Comparison Table

System Type	Limitations	Advantages
Manual System	Slow, error-prone	Simple, no hardware
RFID System	Lost/shared cards	Fast, reliable
QR System	Duplicate codes	Low-cost, easy
Image Matching	Low accuracy	Contactless
Proposed System	Needs setup	Real-time, accurate

4. Proposed Framework

4.1. Algorithm Involved

Using a hybrid algorithmic pipeline, this proposed system incorporates biometric face recognition, driver authentication, and real-time location processing. The face recognition module utilizes a combination of Haar cascade (Haar) face detection and deep feature extraction, using either Local Binary Patterns Histograms (LBPH) or Convolutional Neural Networks (CNN) embeddings, so that students can be accurately identified at the time of boarding, thereby minimizing the potential for proxy attendance. Driver attendance will also be verified by securely logging into the system with hash-matched credentials. The real-time location processing will utilize GPS data on the bus by periodically sampling coordinates and then matching those coordinates to a given map location using the map-matching algorithm. Once the bus is mapped to a specific geographic area, event-based notifications will be generated from the back-end workflows. The back-end algorithms will facilitate the validation of bus pass applications, implement role-based access control, and automatically trigger messages to parents. Overall, these algorithms will collectively provide accurate and reliable methods of ensuring a high level of accuracy, data flow efficiency, and decision-making capability within the transportation ecosystem.

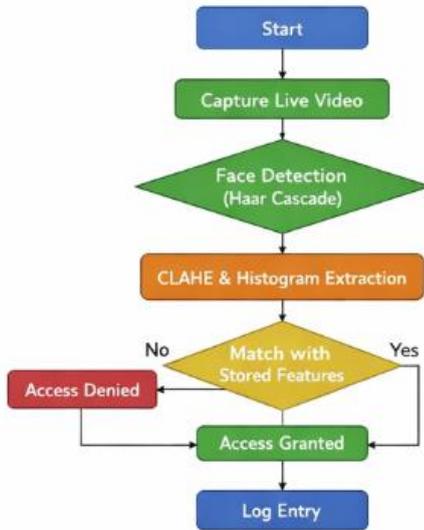


Figure 1 Algorithm

4.2. Main Methodology

Registration of all parties involved in transportation (students, drivers, parents, and administrators) occurs first in the proposed system. Students' biometric data (facial images) is then captured and securely stored for future recognition.

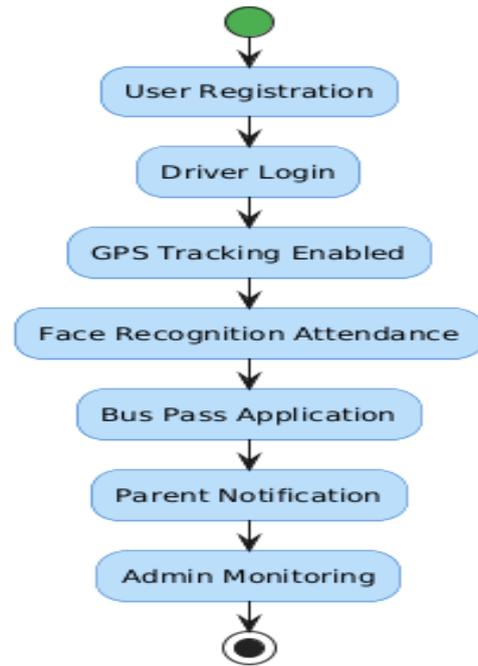


Figure 2 Workflow

The mobile phone numbers of parents are mapped to the corresponding student profile for automatic notifications. Before commencing a route with the bus, the driver must log into the system using an interface that securely authenticates the driver. Once authorized, the bus session is established, which gives access to all functionality dependent on having an active bus session (includes real-time tracking of students, bus attendance, and monitoring of the bus route). After the session is established, the GPS subsystem continuously transmits the latitude and longitude coordinates to the server. The GPS subsystem uses a route-matching algorithm to match the latitude and longitude coordinates with predefined bus routes to provide accurate tracking of the bus.

4.3. Automated Face Recognition Attendance

Students get on the bus by having an onboard camera

Table 2 Algorithm Comparison with Other Deep learning methods

Aspect	Traditional Models	Proposed Approach
Computation	High, GPU-dependent	Low, CPU-friendly
Speed	Slower real-time processing	Fast real-time response
Training Requirement	Requires large datasets	No training required
Model Size	Heavy, memory intensive	Lightweight, minimal storage
Accuracy Under Low Light	Moderate, depends on model	Improved with CLAHE enhancement
Deployment	Complex, high resource demand	Easy, deployable on standard hardware
Scalability	Hardware-limited	Easily scalable on campus systems
Cost	High implementation cost	Low-cost and practical

take a live image of them. The camera looks for facial regions using facial detection algorithms and then uses either LBPH or Convolution Neural Network embeddings to validate their identity.

4.4. Digital Bus Pass Application Verification

Students submit bus pass applications through the integrated portal where the system processes each application to ensure it contains valid information and verifies the student's identity using previously stored biometric information. The system will send each bus pass application to an admin where it can be approved. Once approved, a digital pass will be generated and linked to the student's facial recognition profile.

4.5. Parent Communication Automated Alerts

Using a rule-based notification engine, the system creates and sends out instant messages to parents based upon identified event triggers of bus departures, nearing stoppage points, attendance confirmation, uncovered delays, or route changes as they occur.

4.6. Centralized Admin Monitoring Data Management

The admins have one dashboard that provides real-time monitoring of the bus's location, the driver's current login status, attendance analytics, and workflows in processing pass approvals. The data received from the GPS logs of the busses, the biometric attendance of students submitted by busses, and communication history are all stored on a secure network centralized server. This will give the administrator the ability to manage their operations more effectively and make timely decisions based on the data received from the system.

5. Implementation

5.1. Setting Up the System and Database

In preparation for implementation, configure a centralized database to hold all user information, biometric templates (fingerprints), driver credentials, GPS logs, and notifications about actions taken in relation to bus activity. Secure data schema and API endpoint must be designed to accommodate that will support high-volume transaction (read/write) on/from the database while the Bus is operating.

5.2. Driver Logging onto the System and Initializing the Bus Session

Using either a mobile device or the web, drivers can log onto the system using secure credentials. Once successfully logged onto the system, the system will create an active Bus Session, enable GPS Tracking Services on the Bus, and enable Attendance, and Messaging modules for real-time operation.

5.3. Real-Time GPS Tracking & Live Route Map Updates

A GPS module mounted on the Bus will continually send its location coordinates to the Server. Back-End Services will then determine whether or not the Bus is operating as scheduled (i.e., smooth travelling, stop being made, etc.), update the Live Dashboards accordingly, and provide event-based alerts associated with upcoming Stops, Delayed Arrival, being Off-Route, etc.

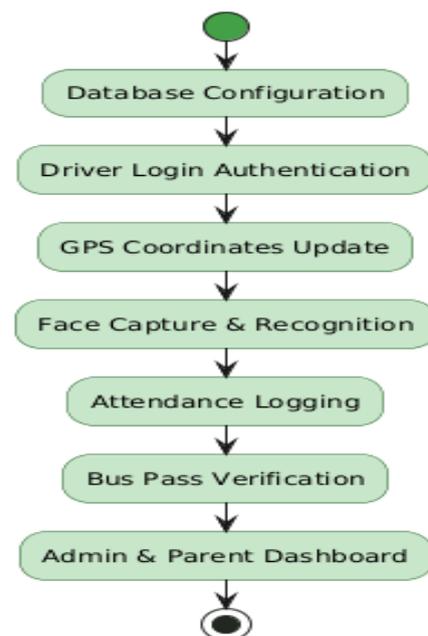


Figure 3 Implementation

5.4. Facial Recognition (Attendance) Pipeline

Cameras mounted at the entrance of the Bus will capture students' images. The very same images will be processed using Detection Models and Recognition Models, validated against existing Student Profiles, and logged as present right away.

5.5. Bus Pass Application Process & Validation

Students will submit Bus Pass Applications through the Portal. The Application will be validated by an

Administrator using the Student Profile data that is stored in the Database.

5.6. Parent/Admin Monitoring Dashboard

The system will include Sync'd Dashboards for real-time tracking of actions taken against a Student, consolidated Attendance Reporting, and Alerts to Parents. This will provide 100% Operational Visibility and Enhanced Safety for all Students.

6. Results and Discussion

A smart campus bus system that was introduced has made substantial gains in relation to: operational effectiveness, safety and coordination between stakeholders. The face recognition module which is used to identify students as they board the bus properly identified students as they boarded the bus thereby reducing the possibility of manual errors and eliminating proxy attendance.

As such, the route that the bus is taking is constantly updated so there is no interruption in the GPS tracking process — this allows parents to see where their children are as they move along the route.

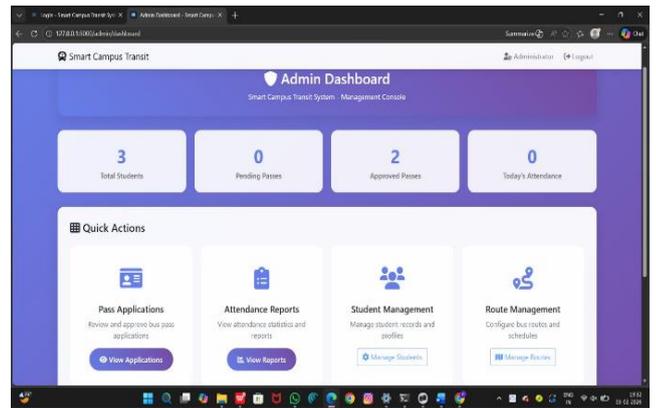


Figure 6 Dashboard

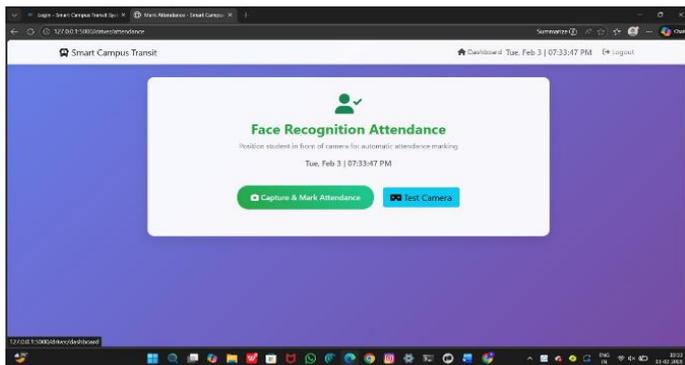


Figure 4 Face Recognition Attendance

Driver login authentication ensures that drivers are held accountable for their actions on the road. The bus is also monitored in real-time by GPS.

One of the most significant outcomes of the system is that there is now a real-time notification system that sends messages to parents informing them of the status of their child's bus in terms of movement, boarding confirmation and arrival time; reducing the uncertainty of whether or not the student's bus has left and increasing parents' trust in the transportation service. The real-time automated alert system that is generated by this system has provided parents with immediate information about specified events as opposed to the traditional message-based system which only delivered generalized information; and as a result has created a more positive experience for parents.

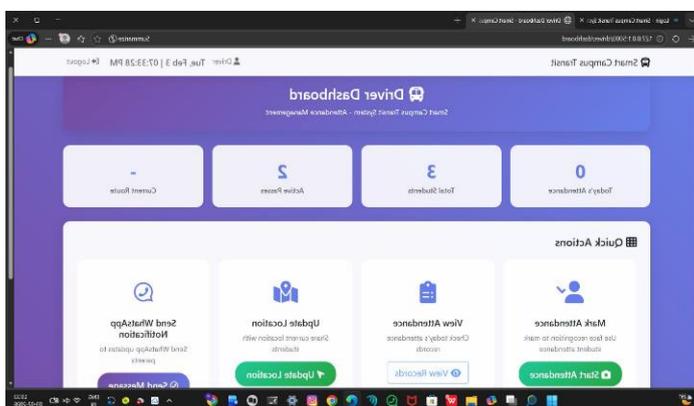


Fig.5.Driver Dashboard

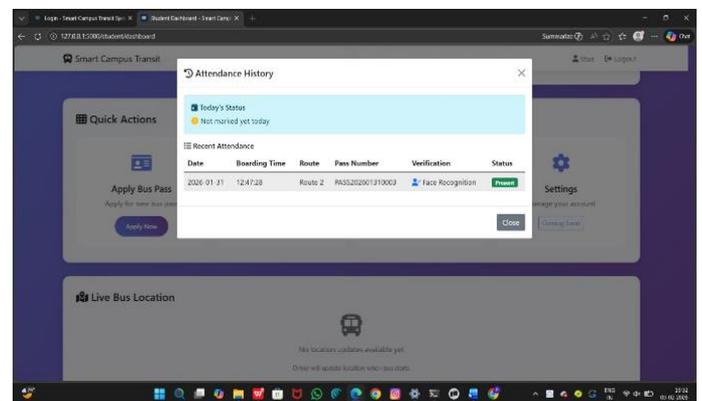


Figure 7 Attendance History



Figure 8 Parent Notification

Finally, this study reinforces the idea that if these types of integrated, digital systems are utilized; they can provide operational transparency and reduce the need for human intervention on the part of the operator.

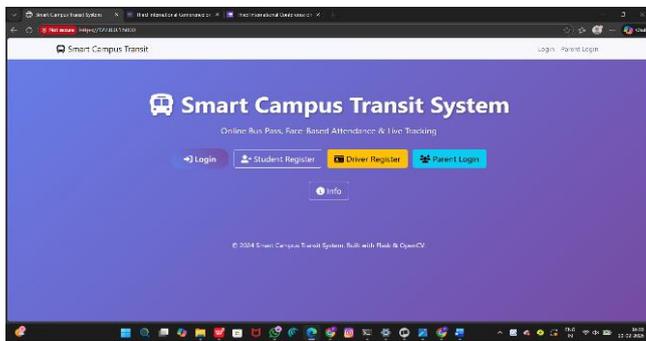


Figure 9 Student Registration

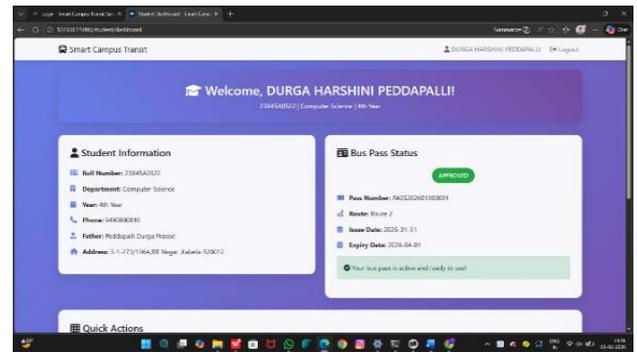


Figure 11 Student Dashboard

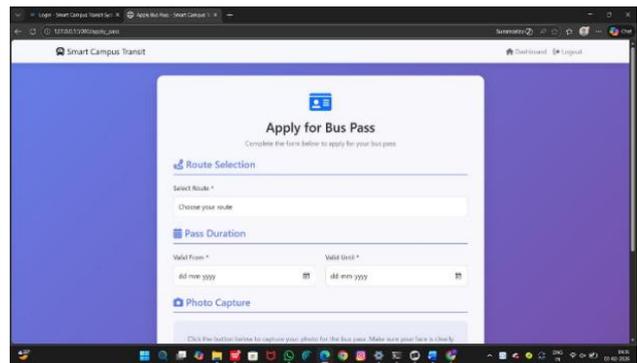


Figure 12 Apply for Bus Pass

From a technological perspective, the results of this study indicate that a smart campus bus system is an effective, scalable solution for providing transportation services to universities. As a result of using multiple biometric verification techniques; such as face recognition and GPS technology; combined with the automated alert system, these systems will provide greater safety protocols and enhance user experience.

The smart facial recognition system developed and tested as part of this project showed continued effectiveness under different real-world scenarios including inside, outside, and low light conditions.

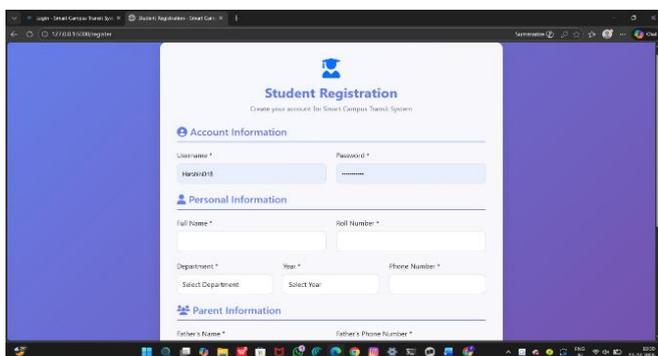


Figure 10 Student Registration

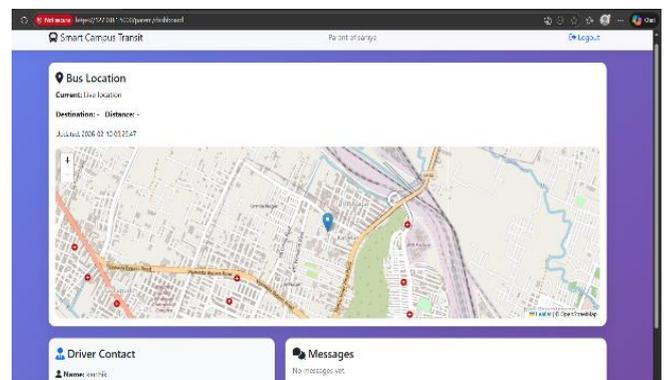


Figure 13 Parent Dashboard

The web-based application created a seamless user experience while interacting with the backend recognition module. Flask provided low-latency communications for image capture, image recognition results return, and storing of transit logs.

Conclusion

The Smart Bus Management System combines multiple functions such as face recognition, attendance records for drivers, accounts for bus passes, GPS (tracking of bus locations) and notifications to parents about their child's bus status into a single cohesive system for managing the transportation needs of a university campus. Automating attendance using face recognition technology, as well as real-time updates to the location of buses helps to improve the efficiency of operations while enhancing the safety of students being transported. In addition, the system's ability to log a driver into the system and provide monitoring of that driver's performance enables greater accountability and governance of bus transportation operations. The notification module designed to communicate between the campus and parents about the status of their student's transportation reinforces the need for transparency and communication between all parties involved. This integrated system will improve the accuracy of information, reduce time required to complete administrative tasks and increase the ability to make informed decisions when managing the transportation needs of students on campus. Additionally, the Smart Bus Management System will move the university transportation infrastructure to a more modern state, provide opportunities to support sustainable and responsible means of transportation, facilitate a more extensive educational and social purpose, and lay the foundation for additional technology advancements to improve the safety and management of students while in transit on campus

Future Scope

- AI-based route optimization
- Mobile app for real-time tracking
- Advanced driver behavior monitoring
- IoT-enabled bus monitoring
- Electric/hybrid buses integration

- Automated attendance verification
- Parent notification via multiple channels
- Data analytics for transport efficiency

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