TED UNIVERSITY

CMPE 491 / SENG 491 Senior Project
General AI Safety Systems Project Proposal
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Analysis Report for General AI Safety Systems

1. Introduction

The **General AI Safety Systems** project is an advanced safety solution aimed at ensuring the security and well-being of children during school-trip transportation by utilizing artificial intelligence and real-time monitoring systems. Modern technology has enabled unprecedented improvements in various sectors, and our project leverages these advancements specifically for enhancing safety in school transportation. School buses are a vital part of students' daily lives, yet they carry inherent risks associated with accidents, distractions, and lack of oversight. Traditional safety measures in school buses are often limited to basic supervision, manual seatbelt checks, and driver monitoring, which can be insufficient in ensuring that safety protocols are strictly adhered to throughout each journey. This project aims to address these limitations by implementing an intelligent, automated system that continuously monitors key safety parameters in real time.

The **General AI Safety Systems** project offers a multifaceted approach to safety, integrating features such as **real-time face recognition**, **seatbelt usage verification**, **behavioral analysis**, and **dynamic route optimization**. Each of these features addresses specific safety needs. For instance, **face recognition** ensures accurate attendance and prevents unauthorized individuals from boarding, providing parents and school officials with a reliable record of each child's bus activity. **Seatbelt monitoring** employs sensors and AI to verify that children are securely fastened at all times, instantly alerting the driver or administrators if a seatbelt is unbuckled during transit. **Behavioral analysis** further contributes to in-vehicle safety by detecting and alerting bus drivers to unsafe actions, such as students standing or moving between seats while the vehicle is in motion. Finally, **dynamic route optimization** leverages real-time traffic data to select the safest, most efficient routes, adjusting in response to unforeseen events like traffic congestion or accidents.

The goal of this project is not only to enhance in-transit safety but also to instill confidence among parents, school administrators, and drivers. By providing a comprehensive safety solution, the system alleviates common concerns regarding student welfare during transportation and fosters a sense of transparency and accountability. Through **advanced image processing** and **instant alerts**, the system maintains a vigilant eye on school bus operations, ensuring that any safety breaches or emergencies are promptly addressed. This automated monitoring allows bus drivers to focus primarily on driving without compromising the safety of the students on board.

This document provides a thorough analysis of the General AI Safety Systems project, discussing its specific objectives, technical requirements, and the critical challenges anticipated during implementation. The analysis explores both **functional and nonfunctional specifications** essential to developing a reliable, secure, and scalable system. The project also considers ethical and legal implications, including data privacy regulations and adherence to child protection standards, making this safety solution not only innovative but also compliant with existing laws and guidelines. By addressing these multiple facets, the report outlines a solution that meets current safety needs while offering a sustainable model for future growth and adaptability.

2. Current System

In the current landscape, safety protocols for school buses heavily depend on manual oversight provided by bus drivers or attendants. This approach, though traditionally employed, presents several limitations in its effectiveness. Bus drivers are typically responsible for monitoring student behavior, ensuring compliance with seatbelt usage, and maintaining safety throughout the journey. However, the inherent challenges of driving and supervising a bus full of students simultaneously limit the driver's ability to observe each child consistently. Furthermore, the driver's primary focus must be on the road, leaving limited attention for detecting noncompliance or potentially dangerous behaviors among the students.

The limitations of the existing system include a lack of advanced technology, which significantly impacts the overall safety and security of students during school transportation. Specific deficiencies in the current setup are as follows:

> **Automated Real-Time Monitoring**: Currently, manual observation is the only means of ensuring seatbelt compliance and appropriate student behavior. However, it is not feasible for drivers or attendants to continuously monitor each child's safety status while also managing their primary duties. This limitation leads to gaps in safety oversight, as issues such as unfastened seatbelts or standing children may go undetected. Without automated assistance, real-time supervision becomes unreliable and inconsistent.
>
> **Real-Time Alerts and Notifications**: At present, there is no automated mechanism to notify bus drivers, parents, or school administrators of safety breaches or issues within the vehicle. If a child unbuckles their seatbelt or exhibits unsafe behavior, the driver may not become aware of it until much later, if at all. This lack of immediate alerting prevents timely responses to potential hazards, as any corrective action depends solely on the driver's situational awareness and ability to detect the issue. Consequently, safety incidents may escalate before they can be addressed, increasing risks to the students on board.
>
> **Dynamic Route Planning**: Current bus routes are generally predetermined, without the flexibility to adapt to real-time conditions like traffic congestion, road closures, or weather changes. This static routing method can lead to longer travel times, increased fuel consumption, and potential exposure to traffic incidents or unsafe areas. A dynamic approach that adjusts routes based on current conditions would allow buses to avoid potential risks, save time, and enhance the overall safety of students during their commute.

These limitations highlight the need for a technologically advanced solution to address the gaps in real-time monitoring, notification, and route optimization. By implementing the proposed AI Safety System, these challenges can be effectively overcome. The system offers a comprehensive solution by providing:

Reliable and Automated Monitoring: AI-driven real-time monitoring reduces the dependency on human oversight and ensures continuous tracking of each student's seatbelt compliance and behavior.

Instant Alerts and Notifications: Automated alerts enable immediate action, notifying the driver and stakeholders of any safety violations, thus allowing timely intervention to prevent potential incidents.

Optimized, Adaptive Route Planning: Dynamic route adjustments improve travel efficiency and safety, making it possible to avoid traffic congestion, hazardous conditions, and other obstacles in real-time.

The proposed AI Safety System stands to not only improve the safety standards of school transportation but also bring a new level of reassurance to parents, drivers, and school administrators.

3. Proposed System

The proposed **AI-based Safety System** is an intelligent solution designed to transform school transportation safety by using artificial intelligence and real-time monitoring. This system aims to address key areas of safety concern within the school bus environment, combining advanced technologies like high-resolution image processing, behavioral recognition algorithms, and real-time route optimization. The system's design ensures continuous monitoring and immediate responses to potential safety violations or concerns, creating a safer transportation experience for students and providing parents, drivers, and school administrators with peace of mind.

3.1 Overview

The AI-based safety system comprises several core components, each designed to address a specific aspect of student safety. Through these integrated technologies, the system provides robust, continuous safety assurance throughout each journey:

1. **Face Recognition for Attendance**: The face recognition feature captures and verifies the identity of each student as they board and exit the bus. High-resolution cameras identify students based on facial features, ensuring an accurate attendance log that can be accessed by parents and school officials. This feature also prevents unauthorized persons from accessing the bus, creating a secure environment.
2. **Seatbelt Monitoring**: Equipped with sensors and AI algorithms, the system verifies whether each student is wearing their seatbelt. If a seatbelt is unbuckled during the journey, an alert is sent to the driver for immediate corrective action. This feature ensures that students remain safely seated and minimizes the risk of injury in the event of sudden stops or collisions.
3. **Behavioral Analysis**: The system employs behavioral analysis to detect unsafe actions within the bus, such as standing, moving between seats, or sudden movements. Advanced algorithms analyze real-time video feeds to recognize specific behaviors that could indicate safety risks. In cases of detected violations, the system sends alerts to the driver and administrators, enabling swift intervention to address the issue.

4. **Dynamic Routing**: The system integrates GPS and real-time traffic data to optimize routes for safety and efficiency. By adapting to current traffic conditions, road closures, and other obstacles, the system can dynamically recalibrate the route to ensure that students reach their destination as quickly and safely as possible. This feature also minimizes travel time, reduces fuel consumption, and lowers the environmental impact.

Together, these components deliver a comprehensive safety solution, establishing a reliable system that enhances security, mitigates risks, and strengthens communication among parents, school officials, and bus drivers.

3.2 Functional Requirements

The system must perform several key functions to achieve its safety objectives:

Face Recognition: High-resolution cameras capture each student's image upon boarding and exiting. The face recognition algorithm verifies identity and logs attendance, creating a reliable record accessible to authorized users. This feature prevents unauthorized access and ensures student accountability.

Seatbelt Usage Detection: Integrated sensors detect seatbelt usage, continuously monitoring whether students are securely fastened. If a seatbelt is unbuckled mid-journey, the system generates an immediate alert for the driver, prompting quick corrective action. This feature is critical for enforcing seatbelt safety, reducing risks of injury.

Behavior Detection: Real-time video processing monitors student behavior, identifying actions such as standing or moving around during transit. These behaviors pose significant safety risks, and upon detection, the system instantly notifies the driver and administrators, ensuring rapid intervention.

Route Optimization: The routing system analyzes real-time traffic conditions, selecting the safest and most efficient path. By recalculating routes as needed, it adapts to changing conditions, avoiding traffic jams, accidents, or hazardous roads, thus reducing travel time and fuel consumption.

Data Transmission and Alerts: The system securely shares real-time data with authorized parties. Alerts are customizable and can notify parents, school administrators, and drivers when specific safety thresholds are met or breached. Data is encrypted to ensure privacy, and notifications are streamlined to facilitate efficient responses to any issues.

3.3 Nonfunctional Requirements

To ensure the system operates effectively, a set of nonfunctional requirements must be met:

Accuracy: The face recognition and behavioral detection algorithms must achieve high accuracy, as errors could compromise student safety or prevent unauthorized access detection. Both hardware (high-resolution cameras) and software components (AI algorithms) must be finely tuned to minimize false positives and negatives.

Performance: Real-time processing capabilities are essential to ensure minimal delay in alerts and notifications. The system must operate efficiently under varying traffic, lighting, and environmental conditions, with real-time data updates and responses critical to effective safety monitoring.

Security: The system must adhere to strict data protection standards, ensuring that sensitive student data is encrypted and securely managed. Compliance with GDPR and child privacy laws is essential, and robust access controls must limit data access to authorized personnel only.

Reliability: The system must function consistently across different environmental conditions, including weather variations, low lighting, and other operational challenges. It must be designed to fail safely, with backup protocols in case of any technical failure.

User Accessibility: The interface must be simple and intuitive, enabling easy navigation by users with varying technical expertise, such as bus drivers, parents, and school administrators. Clear and accessible interfaces enhance user engagement, ensuring stakeholders can quickly access important information.

3.4 Pseudo Requirements

Constraints affecting the system's design and functionality include:

Compliance with Regulations: Adherence to all applicable child safety and privacy regulations, including GDPR, child transport safety guidelines, and local privacy laws, is mandatory. The system must comply with regulations to protect both the children and the schools' reputations.

Ethical Considerations: Ethical handling of student data is essential, with efforts to limit data collection to necessary information only. Sensitive data should be managed with transparency, integrity, and strict access controls to protect children's privacy and earn stakeholder trust.

Cost Constraints: The design must balance performance with affordability, using cost-effective materials and software without compromising quality. Cost constraints also influence hardware choices, potentially impacting resolution, data storage, and system expansion.

Scalability: Designed for broad deployment, the system should support multiple buses and locations without a decline in performance. This scalability allows future expansion across different regions, schools, and transportation providers.

3.5 System Models

3.5.1 Scenarios

Scenario 1: **Attendance Verification through Face Recognition**

1. As students board the bus, cameras capture their faces and verify their identities.
2. The system logs attendance in real time, preventing unauthorized boarding.
3. Parents and administrators can view attendance records through a secure app, providing an added layer of security.

Scenario 2: **Seatbelt Compliance Monitoring**

1. Mid-journey, a child unbuckles their seatbelt.
2. Seatbelt sensors detect the change, triggering an alert to the driver.
3. The driver is notified to take corrective action, and parents receive an alert for transparency.

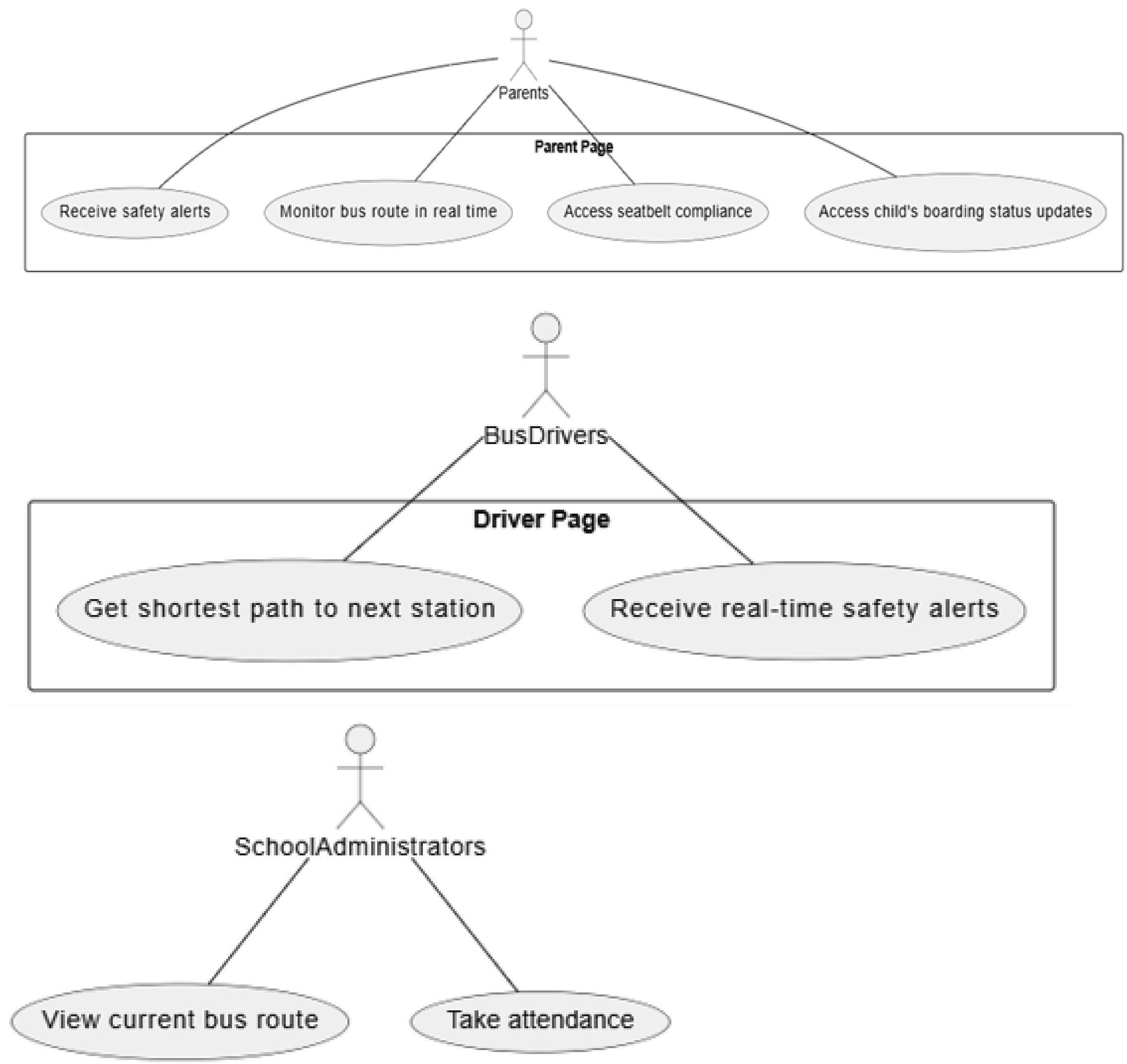
Scenario 3: **Behavior Detection for Unsafe Movements**

1. Cameras detect a student standing or moving while the bus is in motion.
2. An immediate alert is sent to the driver, allowing for timely intervention.

Scenario 4: **Dynamic Route Optimization in Real-Time**

1. Traffic congestion or an accident occurs along the predetermined route.
2. The system recalculates the optimal path, adjusting for the safest and quickest route.
3. Parents receive notifications of route changes, ensuring transparency.

3.5.2 Use Case Model

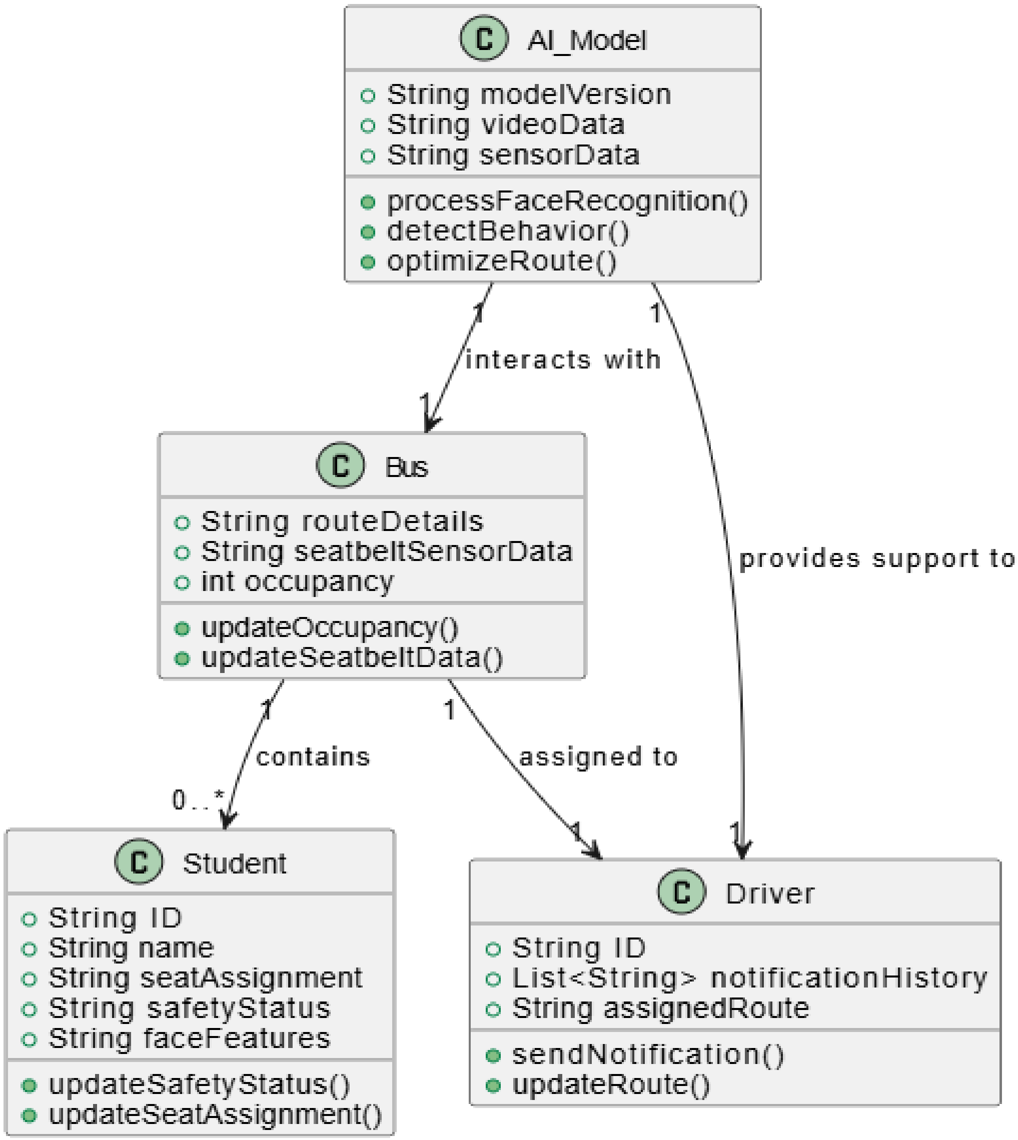


Parents: Access updates on their child's boarding status, seatbelt compliance, and overall safety. They can monitor the bus route in real time and receive alerts for any safety issues.

Bus Drivers: Receive real-time alerts for safety violations, allowing prompt intervention without diverting attention from driving. Also, receive the shortest path to current next station.

School Administrators: Access reports on safety incidents, route adjustments, and student attendance. This feature provides valuable oversight, enhancing operational management across multiple vehicles.

3.5.3 Object and Class Model



The system includes the following objects and classes:

Student: Attributes include ID, name, seat assignment, safety status and face features.

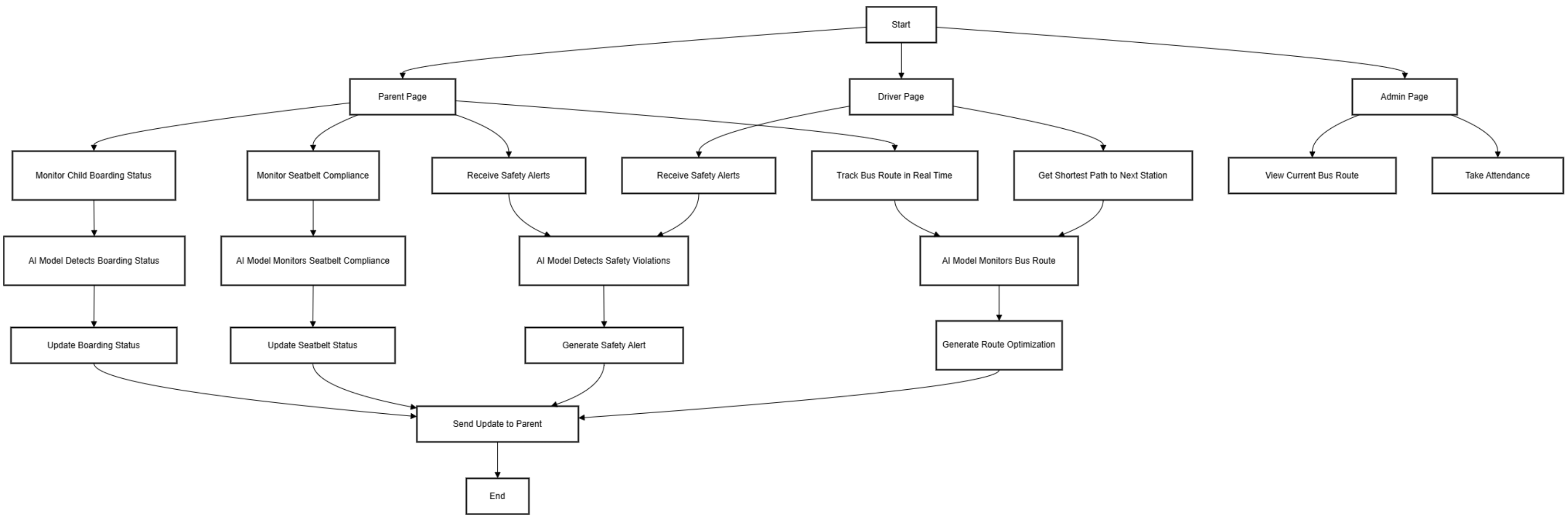
Bus: Attributes include route details, seatbelt sensor data, and occupancy.

Driver: Attributes include ID, notification history, and assigned route.

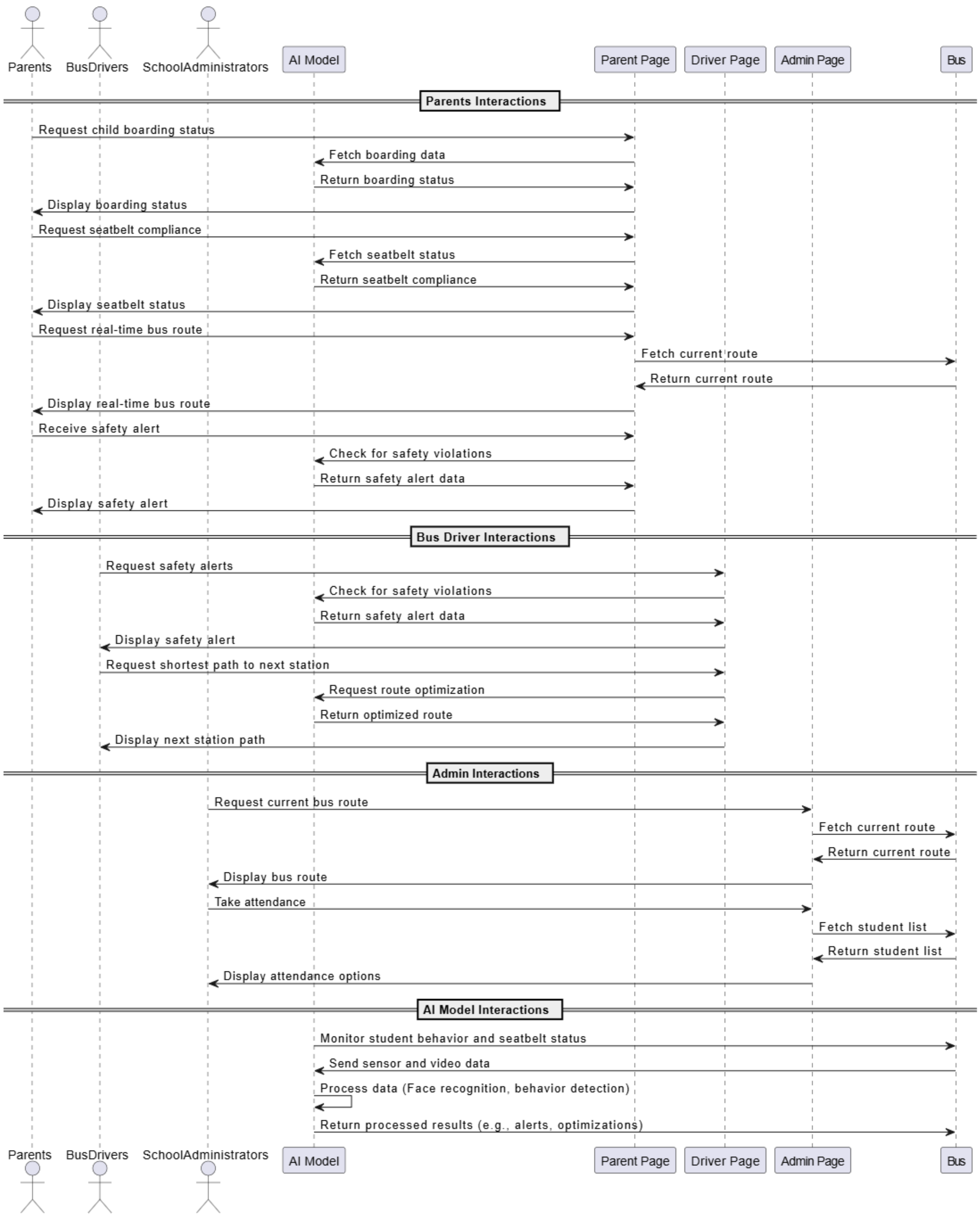
AI Model: Processes video and sensor data to perform face recognition, behavior detection, and route optimization.

3.5.4 Dynamic Models

Data Flow Diagram: Displays the flow from cameras and sensors to the AI processor, then to the notification system, illustrating how data moves through the system in real time to trigger alerts and actions.



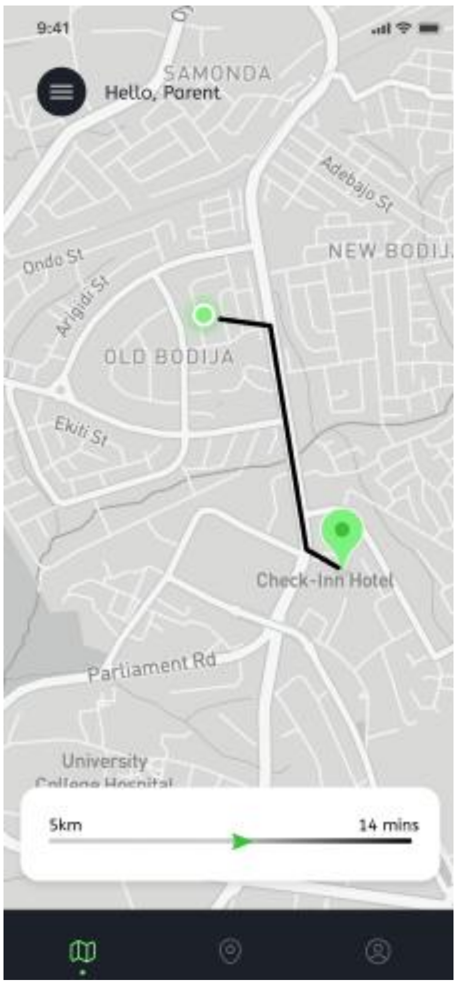
Sequence Diagram: Visualizes the interaction between students, sensors, the AI model, and the alert system, showing actions such as detecting unbuckled seatbelts, identifying unauthorized passengers, and notifying stakeholders.



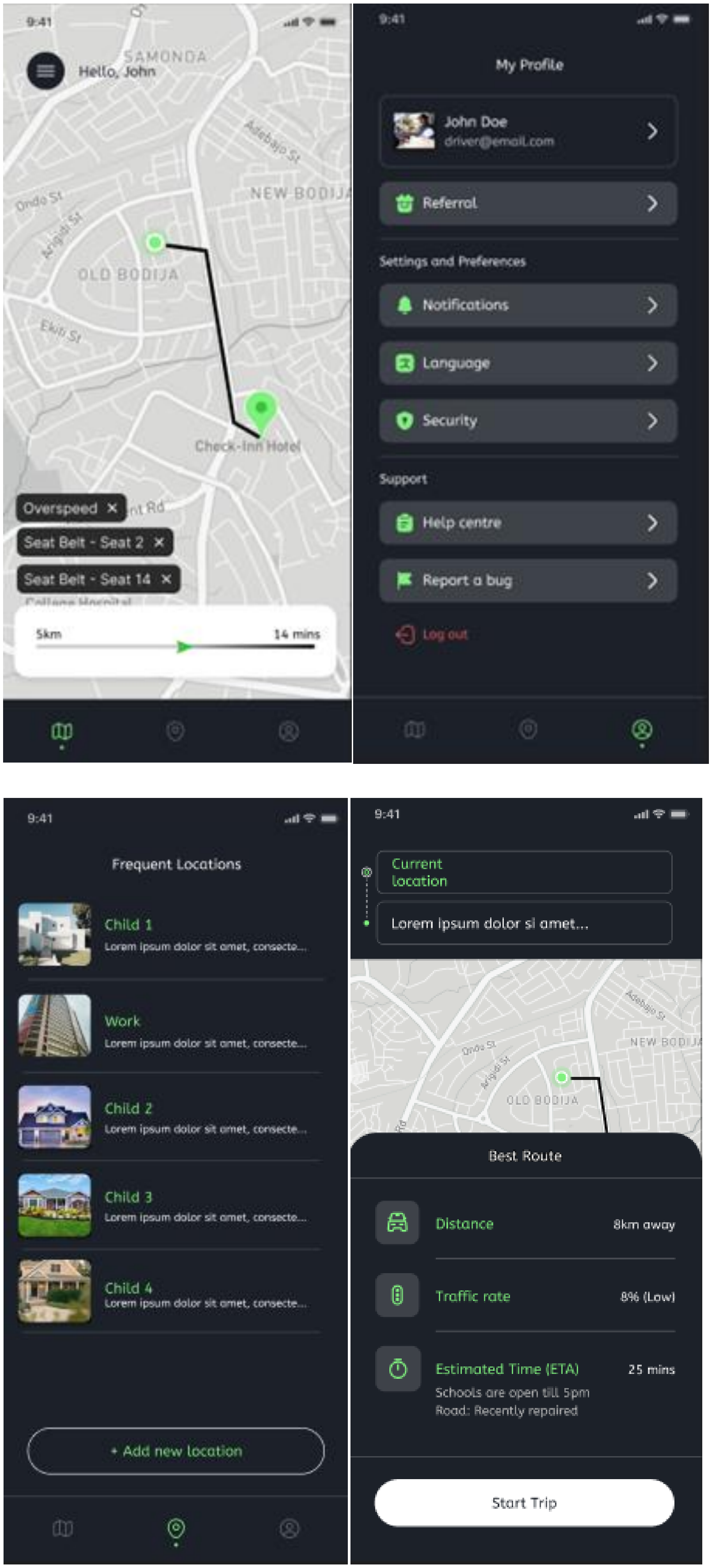
3.5.5 User Interface - Navigational Paths and Screen Mock-Ups

The system will feature user-friendly interfaces tailored to each user group:

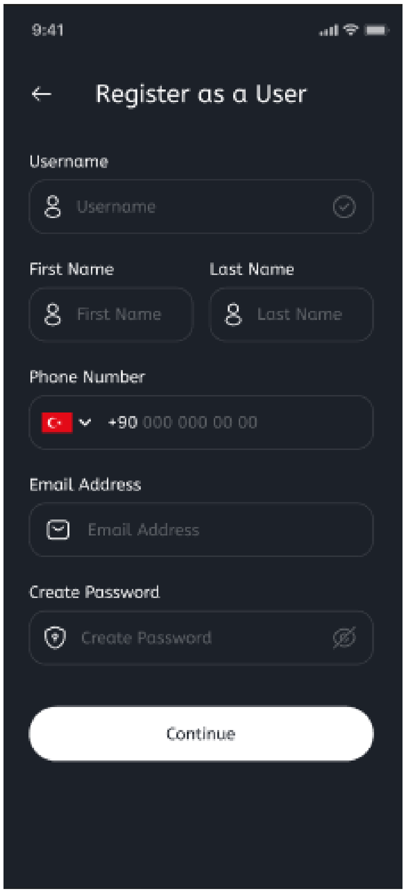
> **Parent Dashboard**: Displays student attendance, real-time route updates, and safety alerts.

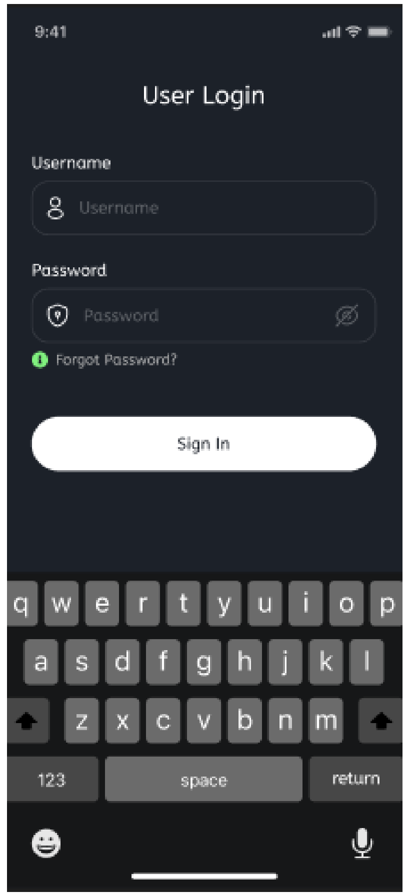


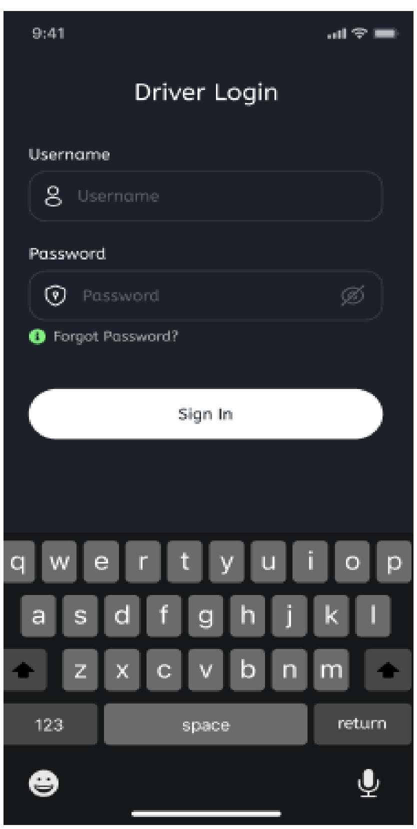
Driver Interface: A control panel providing real-time alerts for safety violations, route optimization updates, and a simplified dashboard for quick interactions.



Login and Register: LogIn and SignUp pages.







4. Glossary

Face Recognition: A sophisticated AI-driven technology that captures and analyzes facial features to verify individual identities. In the context of the General AI Safety Systems project, face recognition is used to identify each student as they board and exit the school bus. This functionality ensures that only authorized individuals are on the bus, improves attendance accuracy, and provides parents and school officials with real-time updates about each child's boarding and deboarding status.

Seatbelt Sensor: A hardware device embedded in each seatbelt that detects whether it is properly engaged or unfastened. The seatbelt sensor continuously monitors the seatbelt's status and is connected to the AI system. In cases where a seatbelt becomes unbuckled during transit, the sensor triggers an alert to notify the driver and administrators, allowing for immediate corrective actions to ensure student safety. This technology reinforces compliance with safety standards and minimizes the risk of injury in case of sudden stops.

Route Optimization: An advanced feature that dynamically adjusts the bus route based on real-time traffic conditions, road closures, and other environmental factors. By utilizing GPS data, predictive algorithms, and live traffic updates, route optimization selects the safest, most efficient path for the school bus to follow. This feature not only minimizes travel time but also reduces fuel consumption and the system's environmental impact, ensuring that students arrive at school or home promptly and safely. Route optimization provides drivers and parents with the most current information on arrival times and route adjustments.

Real-Time Alert System: A critical notification system within the AI Safety System that sends immediate alerts to relevant stakeholders, such as bus drivers, parents, and school administrators, in response to detected safety violations. This system enables proactive intervention by notifying users of safety issues like unfastened seatbelts, unauthorized passengers, or unsafe behaviors. Alerts are customizable based on the preferences and access level of each user and are designed to facilitate timely responses, ensuring student safety is maintained throughout the trip.

Behavior Detection: An AI-based feature that analyzes live video feeds to monitor students' behavior within the bus. The system can identify potentially unsafe actions such as standing, moving between seats, or other behaviors that pose safety risks while the vehicle is in motion. Upon detecting any unsafe behavior, the system sends an alert to the driver and school administrators, allowing for quick intervention and minimizing the likelihood of accidents or injuries.

Data Encryption: A security measure that protects sensitive information transmitted by the AI system. Data encryption ensures that all student data, including attendance records, route details, and real-time monitoring, is securely stored and accessible only to authorized users. Compliance with data protection laws, such as GDPR, is essential, as encryption safeguards the privacy of student information and builds trust with parents and school administrators.

User Interface (UI): The visual platform through which users interact with the system, including the parent dashboard, driver control panel, and admin portal. Each interface is designed with simplicity and ease of use in mind, enabling non-technical users to quickly access essential information, monitor real-time updates, and receive alerts. The UI provides a seamless experience for all stakeholders, ensuring that safety notifications and status updates are readily accessible.

Dynamic Routing Algorithms: Computational models, such as Dijkstra's algorithm or A*, which the system employs to calculate the optimal route based on real-time data inputs. These algorithms process multiple variables, including traffic patterns, road incidents, and environmental conditions, to adjust the bus route dynamically. By continuously recalculating routes, dynamic routing algorithms support the safest and most efficient travel paths for the school bus.

Role-Based Access Control (RBAC): A security protocol that restricts data access based on the user's role within the system, such as parent, driver, or administrator. RBAC ensures that sensitive information is shared responsibly, with each stakeholder receiving only the data and alerts relevant to their role. This feature helps maintain data privacy and enhances system security by preventing unauthorized access to protected information.

5. References

ACM Code of Ethics and Professional Conduct: Guidelines for ethical and responsible behavior in computing.

YOLOv3 Model: Efficient, real-time object detection algorithm ideal for high-speed safety monitoring (Redmon & Farhadi, 2018).

General Data Protection Regulation (GDPR): EU guidelines for data privacy and protection in digital systems.

NHTSA Child Safety Guidelines: Legal and regulatory guidance for child transportation safety.