North South University

Department of Electrical and Computer Engineering

CSE 299: Junior Design

Section: 14

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Project Name: Drive Mind (Smart Road Safety Assistant)

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Project Report

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Introduction:

Road Safety is a major global concern, particularly in overpopulated countries like Bangladesh, where the number of vehicles is increasing, as well as the frequent number of traffic violations. Many road accidents occur because of wrong-way driving on the roadside because of the driver's negligence and lack of awareness and monitoring. These issues are more severe in developing countries, especially in Bangladesh, where advanced safety infrastructure and vehicle-installed driver assistance systems are not widely available. In recent years, advancements in mobile technology have opened new possibilities for intelligent transportation solutions. Modern devices are now equipped with powerful cameras and processors capable of handling real-time computation of big data. Artificial Intelligence (AI) and Computer Vision technologies have made it possible to analyze visual data efficiently on mobile devices without relying on external hardware. Drive Mind is an AI-powered smart road safety assistance mobile application designed to enhance safety by detecting unsafe and wrong-way driving scenarios in real-time. This project integrates Flutter for the User Interface (UI), native Android (Kotlin) for high-performance camera and AI processing, and machine learning models (YOLO with TensorFlow Lite) for vehicle detection. By combining these technologies into a hybrid architecture within a single app, Drive Mind strikes a good balance of performance, scalability, and usability. With the help of these, this app provides a low-cost, easy-to-access and intelligent traffic management assistance solution that runs directly on Android smartphones.

Problem Statement:

Social Problem:

Road accidents remain one of the leading causes of injury and death globally. A significant number of these accidents are caused because of:

- Driving in the wrong direction
- Lack of driver awareness
- Ignorance of traffic rules among drivers
- Inadequacy of traffic management on roads

Most advanced driver assistance systems are expensive and require high-end hardware for the surveillance systems. As a result, most of the traffic managements only rely on traditional traffic-police-based management system. These systems are not feasible to deploy in every place in the city. So, there is a clear need for a cost-effective and easily deployable safety solution that can assist traffic management by detecting wrong-direction traffic movement and

sending them the evidence of detection in real-time. A mobile-based system can bridge this gap by utilizing existing smartphone hardware.

Technical Problem:

From a technical perspective, implementing real-time vehicle detections along with wrong-way direction detection on mobile devices presents several challenges:

- Performing real-time object detection with limited computational resources
- Maintaining secure and scalable data storage
- Processing live camera feeds with low latency
- Ensuring smooth integration between the user interface and AI processing modules
- Providing a responsive and user-friendly experience

Our App addresses these challenges by using on-device AI inference, efficient image preprocessing and a hybrid mobile architecture that leverages the strengths of both Flutter and native Android development.

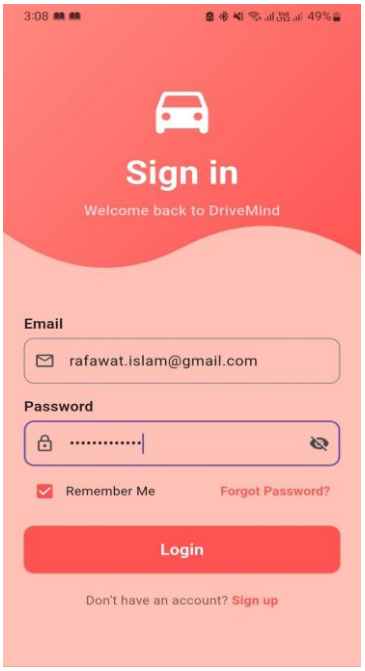
Project Description:

Drive Mind mobile application is based on a hybrid architecture that consists of interconnected modules. Each module consists of a specific role to ensure the system operates efficiently and reliably.

User Authentication Module:

The authentication module ensures that only authorized users can access the system. This includes the following features:

- User registration with username, full name, email, and password
- Strong password validation rules enforcing uppercase letters, lowercase letters, numeric characters, and a minimum length.
- Email verification to confirm user authenticity
- Security questions and answers for account recovery in the future
- Secure login and logout functionality



- Provide the user with a better experience by providing session management after the login period.

Firebase Authentication is used to manage user credentials securely, while Cloud Firestore stores additional user profile information. Similarly, Cloudinary is used to store the profile image of the user, along with storing the URL information for binding the stored profile image of that user. These separations enhance security and scalability by ensuring sensitive authentication data is being handled by Firebase, while application-specific data is being stored in Firestore.

User Interface and Experience (Flutter Frontend):

Flutter serves as the primary frontend framework for Drive Mind. It provides a modern and responsive user interface that enhances usability and accessibility. The UI includes:

- Splash screen with fade animation
- Onboarding screens for first-time users.
- Login and registration screens with real-time validation feedback
- Home dashboard and tab for navigation
- Detection history and profile management pages
- Dark and Light theme support

Flutter's widget-based architecture allows for smooth animations, consistent design, and easy maintenance. State management is handled efficiently to ensure seamless user interactions.

Training Vehicle Detection Model in Google Colab:

To prepare the TensorFlow Lite model to use it in the Android app inference and to perform vehicle detection in the Android app, we trained a PyTorch model using the YOLO object detection algorithm:

- The datasets of different vehicle images are collected for labelling the vehicle object
- Preprocessing the labelled datasets by resizing, auto-orientation and augmentation
- Then prepared a .yaml file to make a JSON array of the labelled object
- With this preprocessing, the datasets were trained using the YOLO object detection algorithm.
- After getting the trained PyTorch model, the inference of the model is done in a Python file.

- Then we convert the trained PyTorch model into a TFLite (TensorFlow Lite) model for further performing of inference and vehicle detection in the app.

The TensorFlow Lite model is used for further real-time vehicle detection using the camera of the mobile.

Real-Time Vehicle Detection Module (Native Android):

Due to TensorFlow model integration issue while using Flutter packages for real-time detection, native Android development is used for camera handling and AI processing. This module is used for:

- Capturing live video frames by enabling the camera using CameraX
- Preprocessing frames by resizing, normalizing, and rotating images.
- Running object detection using the YOLO deep learning model
- Performing inference using TensorFlow Lite converted from the trained PyTorch model using YOLO.
- Displaying detection results over the frame in real-time using a custom Overlay View
- Displaying the resulting frame to show the condition whether the vehicle is in the correct direction or in the wrong direction.

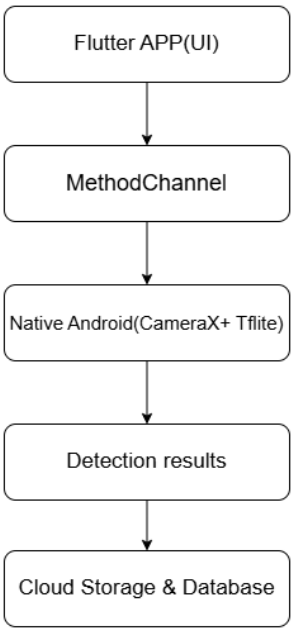
Using native Android ensures efficient resource utilization, which is essential for real-time applications.

Flutter and Native Android Communication:

The Integration between Flutter and native Android is achieved using Method Channel. This communication mechanism allows Flutter to invoke native Android functions and receive results.

The workflow of this:

1. Flutter sends a command to start detection
2. Native Android launches the camera and AI module
3. Detection results are generated
4. Results are returned to Flutter for display and storage

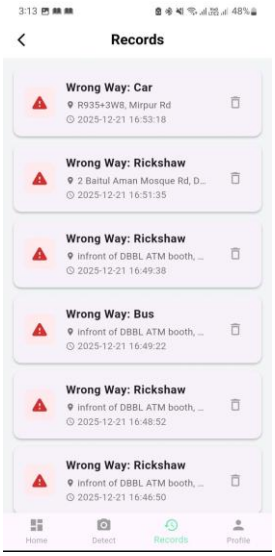


This hybrid communication approach ensures flexibility while maintaining performance.

Detection Records and Cloud Storage:

After a detection event occurs:

- It captures the frame with detection
- Captured images are uploaded to Cloudinary
- Metadata such as timestamp, vehicle type, location, and user ID are stored in Firestore



This allows users to review past detections and maintain a record of unsafe situations. Cloud-based storage ensures scalability and data availability.

Theme and Session Management:

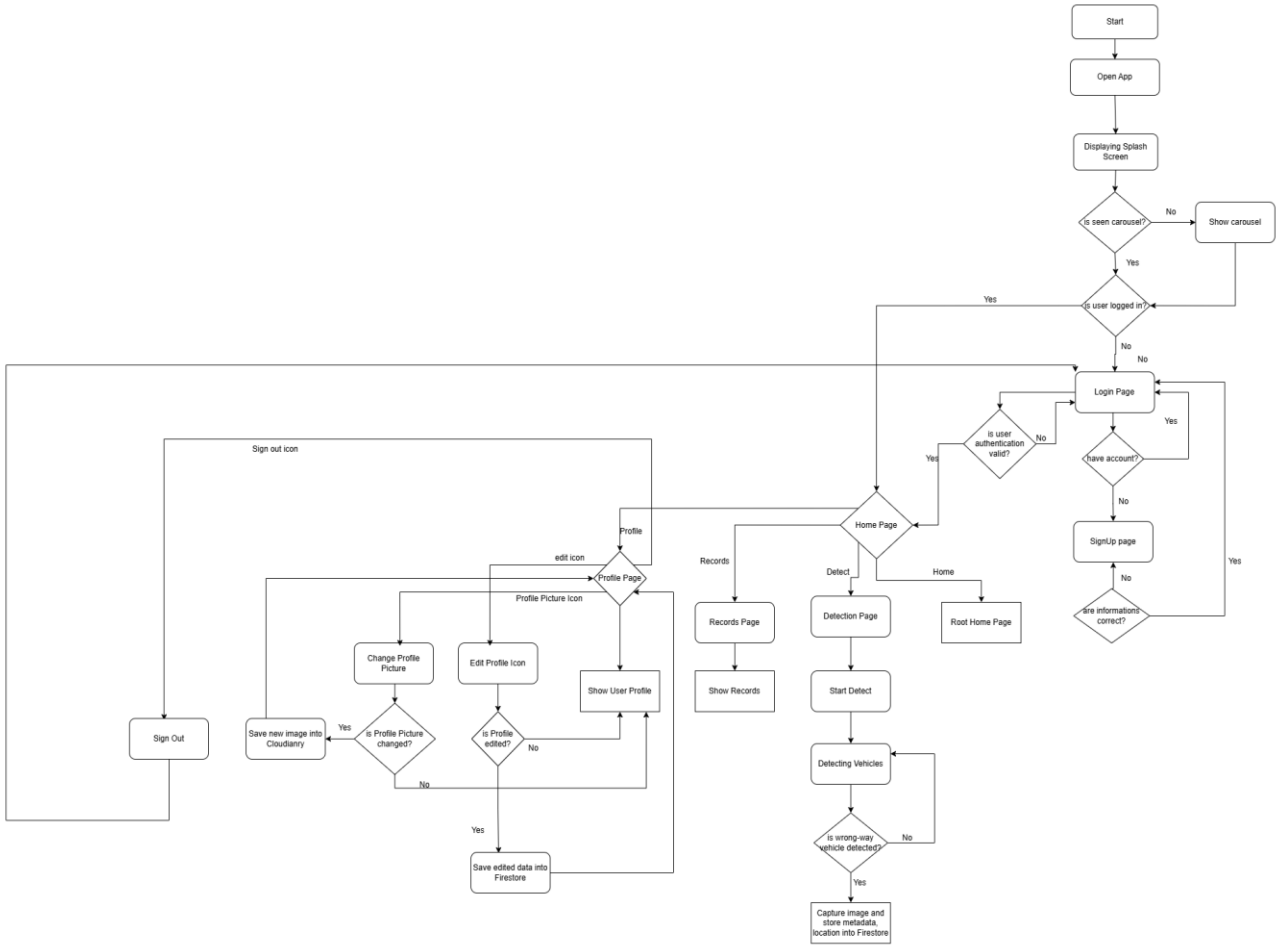
Drive Mind includes user preference management features such as:

- Dark and Light theme switching
- Theme persistence using Shared Preferences
- Session management using the session manager controller

These features improve user experience by providing personalization and maintaining session continuity.

Project Flowchart:

The following flowchart illustrates the interaction between different components of the system:



Technologies Used:

- Frontend Technologies
  - Flutter (Dart)
  - Material Design
  - Provider for state management
- Native Android Technologies
  - Kotlin
  - CameraX
  - Custom overlay rendering
- Artificial Intelligence Technologies
  - YOLO object detection model

    - TensorFlow Lite
    - Image preprocessing techniques
- Back-end and Cloud Services
    - Firebase Authentication
    - Cloud Firestore
    - Cloudinary
- Development Tools
    - Android Studio
    - Visual Studio Code
    - Firebase Console
    - PyCharm
    - Google Colab
    - Jupyter Notebook

Cost Analysis:

Hardware Cost:

- Mid-range phone: 40,000 BDT or higher
- Graphics Card for training YOLO model using dataset on PC: 38,000 BDT or higher (Nvidia RTX 3060 or higher)

Operational Cost:

- Firestore storage & operations: $20-$100 per month
- Authentication: $5-$30 per month
- Cloud Functions: $5-$20
- Hosting/bandwidth: $10-$50
- Cloudinary Plus plan: $89-$99 per month
- Cloudinary Advanced plan: $224-$249 per month

Combined Cost:

Firebase: $40-$200 per month

Clouding Advanced: $89-$99 per month or $224-$249 per month

Total (Estimated): $129-$299 per month or $264- $449 per month

Conclusion:

Drive Mind (Smart Road Safety Assistant) was developed to address one of the most critical and persistent problems in modern transportation systems—road

safety, particularly wrong-way driving and traffic rule violations. Through this project, we successfully demonstrated how mobile devices, when combined with Artificial Intelligence and Computer Vision, can be transformed into powerful, low-cost safety tools without the need for expensive infrastructure or specialized hardware. The application integrates a hybrid architecture that leverages Flutter for a responsive and user-friendly interface and native Android (Kotlin) for high-performance real-time camera processing and AI inference. By training a YOLO-based vehicle detection model and deploying it using TensorFlow Lite, the system can detect vehicles and identifying wrong-direction driving scenarios in real time. The use of on-device inference ensures low latency, improved privacy, and reduced dependency on continuous internet connectivity. In addition to detection, Drive Mind provides secure user authentication, cloud-based storage of detection records, and an intuitive dashboard for reviewing past incidents. The integration of Firebase, Cloud Firestore, and Cloudinary ensures scalability, reliability, and efficient data management. Features such as theme customization, session management, and smooth navigation further enhance the overall user experience. Overall, this project proves that a smartphone-based intelligent road safety system is both feasible and effective. Drive Mind offers a practical solution that can assist traffic monitoring authorities and raise driver awareness, especially in developing countries like Bangladesh where traditional traffic surveillance systems are limited. With further improvements—such as GPS-based location tagging, real-time alerts to authorities, multi-lane analysis, and model optimization—the system can be expanded into a more comprehensive smart traffic management platform. This project lays a strong foundation for future research and development in intelligent transportation systems and mobile AI applications.

GitHub Repository:

Drive Mind (Smart Road Safety Assistant)