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Design and Implementation of a Road Sign and Road State Mobile Notification Application

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1. Introduction

The ever-changing road environment necessitates real-time awareness of road signs and conditions for safe and efficient driving. This report documents the comprehensive requirement gathering process conducted for the development of a Road Sign and Road State Mobile Notification Application. Effective requirement gathering is crucial for the success of any mobile application by ensuring it meets user needs, delivers real value, and avoids costly development pitfalls. The report details the various stakeholder groups involved, user research methods employed, and the identified functional and non-functional requirements that will serve as the foundation for the application's design and development.

While there are many applications that attempt to present the driver with directions to the destination, there aren't many that help simultaneously inform the driver of other necessary information simultaneously. These applications mostly focus on delivering the queried information to the driver like the location of certain places and the distance to the next turn. Information about processing real-time information for the navigator on the road is not prioritized by advanced applications like Google Maps. Our application attempts to fill the disparity between the user view and the application.

This project aims to leverage mobile technology and real-time data sources to create a dynamic and interactive platform for delivering road sign information and updates on road conditions to drivers. The mobile application will utilize GPS location tracking and crowdsourced data to provide users with relevant information about road signs, hazards, construction zones, and other critical factors affecting road safety.

2. Reasons for Requirement Gathering

The software development process can be complex and expensive, with numerous opportunities for errors and miscommunications. Requirements gathering is critical to ensuring that the system being built meets the needs of its users, operates as expected, and delivers value to the organization. Here are a few reasons why requirements gathering is so important:

- **Helps ensure stakeholder alignment:** By involving stakeholders in the requirements gathering process, you can help ensure that everyone is on the same page about what the system needs to do and how it should work. This can help reduce misunderstandings and disagreements later in the development process.

- **Reduces the risk of project failure:** When requirements are not clearly defined, it's more likely that the resulting system will not meet the needs of its users. This can result in project failure, wasted resources, and damage to the reputation of the development team or organization.
- **Defining Functionalities:** By gathering requirements, the development team can define the functionalities and features of the application, such as real-time data integration, notification customization, and seamless navigation integration.
- **Improving Road Safety:** Thorough requirement gathering enables the development of a user-friendly and intuitive application that contributes to improving road safety by providing timely information and updates to drivers.
- **Enables more accurate project estimation:** By clearly defining requirements upfront, development teams can more accurately estimate the time and resources needed to complete the project.
- **Addresses Regulatory Concerns:** Requirement gathering uncovers any legal or regulatory requirements related to the app's functionality.

3. Why Requirement Gathering is Crucial for Our Road Sign and Road State Mobile Notification Application

Effective requirement gathering is essential for the success of our Road Sign and Road State Mobile Notification Application for several key reasons:

- **Understanding Driver Needs:** Our primary goal is to create a mobile application that addresses the real-world challenges faced by drivers regarding road sign awareness and road state changes. Through user research techniques like interviews, surveys, and user reviews, we can gain a deep understanding of user needs, pain points, and desired functionalities. This ensures the application caters to their specific requirements and delivers a valuable solution.
- **Ensuring Road Safety:** Our application aims to promote safe driving by providing real-time information about road signs and road conditions. Requirement gathering allows us to identify critical functionalities that directly impact road safety. For example, understanding user preferences for notification types (e.g., stop sign alerts, speed limit changes) ensures the application prioritizes crucial information that helps drivers make informed decisions while navigating.
- **Avoiding Feature Creep and Cost Overruns:** A clear understanding of project scope, established through requirement gathering, prevents the

uncontrolled addition of unnecessary features during development. This phenomenon, known as "feature creep," can lead to cost overruns, project delays, and a final product that deviates from user needs .By focusing on core functionalities identified through user research and stakeholder analysis, we can ensure efficient development and deliver an application that truly meets user expectations.

- **Developing a User-Friendly Interface:** Usability testing and user persona creation are crucial aspects of requirement gathering. Understanding user behavior and preferred interaction styles allows us to design a user interface that is intuitive, minimizes distractions while driving and caters to a wider range of users, including those with disabilities.
- **Integration with Existing Systems:** Our application may require integration with real-time data sources like traffic management APIs and weather services. Requirement gathering allows us to identify the specific functionalities needed for this integration, ensuring seamless data exchange and accurate information delivery within the application.

4. Requirement Gathering Techniques

We will employ a multi-pronged approach to gather requirements for our Road Sign and Road State Mobile Notification Application:

4.1.Stakeholder Identification:

The first step involves identifying all stakeholders involved in the project, including:

- **Target Users:** Drivers who benefit from real-time road information and road sign notifications.
- **Transportation Authorities:** Government agencies responsible for maintaining road infrastructure and providing traffic data.
- **Potential Partners:** Companies offering map data or navigation services that could be integrated with our application.

4.2. User Needs Elicitation:

We will employ various techniques to gain a deep understanding of user needs and their current methods for obtaining road sign information and road state updates:

- **User Interviews:** One-on-one interviews with drivers will provide in-depth insights into their experiences, preferences, and challenges related to road signs and road state awareness. Here are some potential interview questions:
 - What are the biggest difficulties you face regarding road signs while driving?

- How do you currently stay informed about traffic conditions and road closures?
- What features would be most helpful in a mobile application for road signs and road state information?
- **Surveys:** Distributing online or paper-based surveys can reach a wider audience and provide valuable quantitative data on user needs and desired functionalities. Here are some potential survey questions:
 - How often do you encounter unexpected road signs or changes in road conditions while driving?
 - Would you be interested in receiving notifications for specific types of road signs (e.g., stop signs, speed limit changes)?
 - What features would be most important to you in a mobile application for road signs and road state information (e.g., real-time updates, customizable alerts, integration with navigation apps)?
- **User Reviews:** Analyzing existing reviews of similar mobile applications can reveal user dissatisfactions and areas for improvement, informing the development of our application to address these shortcomings. Look for reviews of applications like Waze, Google Maps, and other navigation apps with traffic features.

5. Proposed System

5.1. Overview

This project leverages machine learning and potentially Augmented Reality to create an information-rich driving experience. The application will provide the user with a real-time view of the road overlaid with additional information to enhance decision-making. Here's a breakdown of the features we plan to implement, prioritized based on development complexity and resource requirements:

5.1.1. Priority Features

1. **Sign Detection:** The application will help users be aware of the traffic signs that might mentioned exists due to the dataset we will use. It is a dataset consisting of 80000 samples from 150+ classes [5]. The implementation of this feature will also utilize Convolutional Neural

Networks. The feature assists the user to prevent violation of signs that might lead to other consequences like fines

2. Road Condition Updates: The application will integrate data from various sources like traffic cameras, weather sensors, and potentially crowdsourced reports to provide users with real-time updates on:

- Traffic congestion.
- Accidents.
- Weather-related hazards.
- Road closures.

3. Real-Time Road Sign Information: Building upon sign detection, this feature will display information about identified signs directly within the AR view. This includes:

- Sign meaning and significance explanations.
- Visual representations of the signs for enhanced recognition.

5.1.2. Optional Feature (Dependent on Resource Availability and Device Compatibility)

6. Augmented Reality Supported Navigation: The feature will provide the user the directions to navigate by showing arrows in the augmented reality view. It will also display road boundaries and turns. The user will be able to view the road as well as the directions. The feature will be implemented using image processing and computer vision techniques. Deep Neural Network methodologies like, Road and road Boundary detection Network (RBNet), are available for road boundary and region detection. We will additionally use Google Maps API to fetch directions.

Our first goal is to finish implementing feature number 1 (see above). The features here are numbered based on the priority we have assigned to them. Therefore, the flow of implementation will also follow that. Our end goal is to finish the implementation of all the features we have listed above. However, this might change due to the long-developing process of the AR navigation system. The below-mentioned feature will only be implemented if we can successfully implement the above-mentioned features and the devices used to test the application can work effectively in the presence of other features. This latter constraint exists due to the presence of limited computational power of mobile phones and the fact that we are not yet tech savvy to work on Augmented Reality, which is heavier than other simple features.

5.1.3. Future Feature (Highly Dependent on Resource Availability and Device Compatibility)

7. **Crash Detection:** Assisting our users during times of danger like car crashes is a feature that we want to include. The feature detects a car crash by using Computer vision. Then, it notifies the emergency service to respond to the car crash. The feature might be able to save the lives of people by immediately contacting the concerned authorities. However, we need to consider the hardware limitations of mobile devices when implementing this feature. We are working on a possible feasible solution for this feature.

5.2. Functional Requirements

5.2.1. Location-Aware Information and Navigation:

- **Location-based Information:** The application will use GPS to determine the user's location and display relevant road sign information overlaid on a map. This map integration will allow users to visualize their surroundings and road sign placements.
- **Real-time Road State Updates:** The application should provide real-time information about road conditions, including traffic congestion, accidents, construction work, and road closures.
- **Interactive Maps:** Users should be able to view road conditions on interactive maps, with options to zoom in, switch between different map views (e.g., satellite, terrain), and search for specific locations.
- **Navigation Integration (Optional):** The application will explore integration with popular navigation apps (e.g., Google Maps, Waze) to allow users to view road sign information and real-time updates within their preferred navigation interface. APIs or libraries will be investigated to facilitate this integration.
- **Augmented Reality Navigation (Optional):** The application will leverage Augmented Reality (AR) to provide turn-by-turn navigation instructions directly overlaid on the user's view of the road using the device's camera. Arrows superimposed on the road scene will guide the driver and clearly indicate upcoming turns. Integration with image processing and computer vision techniques will enable real-time road boundary and lane detection, enhancing navigation accuracy.

5.2.2. Traffic Light and Sign Detection

- This project needs to use the live camera footage of the user to analyze it frame by frame.
- Using this camera footage, the application has to constantly make image analysis to be able to detect the presence of traffic lights and traffic signs visible.
- For traffic lights, we need to inform the user by showing the color of the light on the phone screen and giving a pop-up sign when it spots a red light.
- For traffic signs, we need to inform the user about any sign spotted and what the sign is about. Signs will be classified and shown on the phone screen where signs that require further attention such as stop signs can also have additional pop-up messages for the purpose of alerting.

5.2.3. Pedestrian Detection (Optional)

- We need to use the phone camera of the user to analyse live camera footage frame by frame.
- By getting the camera footage as input, the application has to constantly make image analysis to be able to detect the presence of any pedestrian that is spotted on the road
- When the application spots a pedestrian, it needs to mark it on the screen and furthermore show an accompanying warning message for alerting purposes.

5.2.4. Requesting Help and Crash Detection (Optional)

- The user will be able to enter phone numbers as “urgent contact” information.
- When the user is in need, he/she will be able to press the SOS button of the application so that the application sends an automatic message to the urgent contact numbers stating that the user may be in a problematic situation together with the location of the user.
- The SOS feature of the application can be also activated automatically if the application detects a sound that may resemble a car crash sound. In that case, the application asks the user if there is a problematic situation. If the user fails to respond in a given duration, the application will accept this as an urgent issue and automatically alert the urgent contact numbers.

5.2.5. User Reporting

Users will be empowered to contribute to the overall road state awareness by reporting incidents or hazards they encounter on their

journeys. This functionality will allow for crowdsourced data collection, improving the accuracy and real-time nature of road condition information within the application.

5.2.6. Route Planning

The application should offer route planning functionality, considering road conditions, traffic congestion, and estimated travel times.

5.2.7. User Profiles

Users should be able to create profiles, customize their preferences, and save frequently used routes for quick access.

5.3. Non-functional Requirements

5.3.1. Reliability

- **Accurate Navigation Information:** The application must consistently provide accurate route planning, direction arrows, traffic light and sign recognition, and SOS message delivery with user location.
- **Minimized Interruptions:** The application should operate smoothly with minimal interruptions throughout a car trip, ensuring uninterrupted navigation and service delivery from initiating navigation to reaching the destination (assuming sufficient battery and network connectivity).

5.3.2. Performance

- **Real-time Processing:** The application should achieve a high frame rate during live camera feed processing to minimize delays in information display and user interaction.
- **High Detection Accuracy:** The implemented detection models for traffic lights, signs, and pedestrians must demonstrate high accuracy to ensure reliable information delivery.
- **Touch Screen Responsiveness:** The application needs to deliver a seamless user experience with a fast response time for touch screen interactions.
- **Efficient Mobile Performance:** The application should be optimized to function effectively within the limitations of mobile hardware, ensuring smooth operation without being overly resource-intensive.

5.3.3. Usability

- **Broad User Accessibility:** The application should be designed with a wide range of user demographics in mind, catering to drivers with varying levels of technological experience.
- **Simple and Responsive Interface:** The user interface needs to be highly responsive, uncluttered, and designed to minimize user interaction complexity while driving. This includes ensuring large, easily identifiable buttons, clear information presentation, and short response times (under a minute).
- **Minimized Driver Distraction:** The application should prioritize minimizing distractions for drivers. This can be achieved by avoiding intrusive sounds, maintaining a clean UI layout, and minimizing user input requirements (e.g., auto-closing pop-ups after a reasonable time).

5.3.4. Security and Privacy

- **Data Protection:** The application must employ robust security measures to protect user data privacy, including location information, notification preferences, and any user-generated content.
- **Data Encryption:** Sensitive data should be encrypted both in storage and during transmission to minimize the risk of exposure in case of potential security breaches.

5.4. Additional Considerations:

- **Battery Consumption:** The application should be optimized to minimize battery drain on mobile devices during extended use.
- **Offline Functionality (Optional):** Explore the possibility of enabling limited functionalities (e.g., pre-downloaded map access) even in areas with weak or no network connectivity.

6. Conclusion

This report has outlined the importance of requirement gathering and detailed the various techniques we will employ to gather requirements for our Road Sign and Road State Mobile Notification Application. By involving stakeholders, understanding user needs, and defining clear functional and non-functional requirements, we will lay a strong foundation for the development of a valuable and user-friendly mobile application. This comprehensive requirement gathering process ensures the application addresses the core needs of its target users, promotes a safe driving experience, and delivers real value on the road.

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