Software Requirements Specification

for

SafeDrive

An AI-based road sign detection system

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1. Introduction

1.1 Purpose

The purpose of SafeDrive is to develop and evaluate advanced deep learning models, including NAS-YOLO, YOLOv7, and YOLOv8, for the detection of road signs. By achieving state-of-the-art accuracy on a road sign dataset from Kaggle, the project aims to contribute to road safety by enabling more reliable and efficient road sign detection systems. This research will potentially reduce accidents and improve overall traffic safety, making roads safer for all users. The project also intends to disseminate its findings through a research paper, fostering knowledge sharing and advancements in the field of computer vision and road safety. Ultimately, the goal is to facilitate the adoption of robust road sign detection systems in real-world applications to enhance road safety worldwide.

1.2 Intended Audience and Reading Suggestions

❖ **Academic Researchers:**

Abstract, Introduction, and Literature Review: These sections provide an overview of the project's goals, significance, and context within the field of computer vision.
Methodology and Model Architectures: Researchers may be interested in the technical details of your chosen models (NAS-YOLO, YOLOv7, YOLOv8) and how you implemented them.
Experimental Results and Analysis: This section provides insights into the performance and comparative analysis of the models, which can be valuable for researchers working on similar problems.
Conclusion and Future Work: Researchers may be interested in your conclusions and potential future research directions in the field of road sign detection.

❖ **Transportation and Traffic Safety Professionals:**

Abstract and Introduction: These sections provide an overview of the project's potential impact on road safety.
Results and Discussion: Insights into the accuracy, efficiency, and real-world applications of road sign detection models are crucial for professionals working on traffic safety.

❖ **Policy Makers and Government Authorities:**

Abstract and Introduction: These sections explain the project's relevance to road safety and its potential to reduce accidents.

Discussion of Applications: Emphasize the practical applications of your research in improving road safety.

Conclusion and Recommendations: Provide clear recommendations on how the research findings can be implemented in traffic management and policy decisions.

❖ **General Audience:**

Abstract and Introduction: These sections provide a high-level understanding of the project's significance.

Visualizations and Figures: Include visual aids and figures that can help convey the impact and importance of your research.

Conclusion and Future Implications: Summarize the project's potential to enhance road safety and prevent accidents in a more accessible language.

1.3 Project Scope

The project scope revolves around developing and assessing deep learning models, specifically NAS-YOLO, YOLOv7, and YOLOv8, for the precise detection of road signs in images and videos. Its primary goal is enhancing road sign detection technology to advance road safety. This encompasses model implementation, dataset utilization, data preprocessing, training, and performance evaluation, with a particular focus on comparative analysis between the models. The research findings will be consolidated into a research paper for knowledge dissemination. However, it's important to note that the project does not include the real-time deployment of the models, hardware development, road sign design, or the recognition of specialized signs, and it does not delve into the legal or policy aspects of implementation. This project scope provides a clear outline of the project's boundaries and objectives, ensuring a focused and achievable research endeavour.

2 Overall Description

2.2 Product Perspective

SafeDrive serves as a crucial component in the larger ecosystem of road safety and traffic management solutions. These models can be integrated into various transportation and automotive systems, including autonomous vehicles, advanced driver-assistance systems (ADAS), and smart traffic management systems. They enhance the ability of these systems to recognize and respond to road signs accurately, ultimately contributing to safer and more efficient transportation networks.
Additionally, the research findings and models could potentially be adopted by companies specializing in computer vision and transportation technology, leading to the development of commercial products designed to prevent accidents and improve road safety.
In summary, the project's product perspective envisions its road sign detection models as integral elements in the evolution of transportation and safety technologies, with potential applications in various products and systems aimed at enhancing road safety and traffic management.

2.3 Product Features

- Real-time Detection: The models offer real-time road sign detection capabilities, ensuring timely recognition and response to changing traffic conditions.

- Multi-Sign Detection: The ability to detect and classify various types of road signs, including regulatory, warning, and informational signs.

- High Accuracy: High precision and recall rates, minimizing false positives and false negatives in road sign detection.

- Adaptability: The models can adapt to different weather conditions, lighting, and road environments, ensuring robust performance in diverse settings.

- Scalability: Scalable architecture that can accommodate additional road sign classes and new sign designs as they emerge.

- ❖ Low Latency: Minimal processing time for quick decision-making, especially critical in autonomous vehicles and ADAS.

- ❖ Customization: The flexibility to fine-tune the models for specific regions or unique road sign requirements.

- ❖ Compatibility: Integration compatibility with existing ADAS and traffic management systems.

- ❖ Data Logging and Reporting: The capability to log and report detected road signs and their locations, aiding in traffic analysis and reporting.

- ❖ Alerting Mechanism: An alert system that notifies the driver or relevant authorities when a critical road sign is detected, ensuring immediate action.

- ❖ Firmware/Software Updates: Support for firmware or software updates to continuously improve model performance and accommodate evolving road sign standards.

- ❖ User Interface: A user-friendly interface for configuring model parameters, viewing detection results, and accessing system logs.

- ❖ Data Privacy: Implementation of privacy measures to protect the data collected during road sign detection.

- ❖ Robustness: Resistance to adversarial attacks and noise to maintain reliability in real-world scenarios.

- ❖ Compliance: Compliance with industry standards and regulations related to road safety and computer vision technology.

2.4 User Classes and Characteristics

- Automotive Manufacturers and Developers:

Characteristics: These users are interested in integrating your road sign detection models into their vehicles and ADAS systems. They require models that are highly accurate, reliable, and capable of real-time processing. They may also need customization options to adapt the models to different vehicle types and regions.

- Transportation Authorities and Traffic Management Agencies:

Characteristics: These users aim to enhance road safety and traffic management. They need models that can be integrated into traffic control systems, surveillance cameras, and smart traffic management infrastructure. Accuracy and scalability are crucial for handling large volumes of traffic data.

- Research and Academic Institutions:

Characteristics: Researchers and academics may use your models for further study and development. They require models with well-documented methodologies and benchmark results. Customization options and access to the dataset for experimentation could also be valuable.

- Autonomous Vehicle Developers:

Characteristics: Developers of autonomous vehicles rely on robust road sign detection models to enable safe navigation. Low latency, high accuracy, and adaptability to various environmental conditions are essential characteristics. Compatibility with autonomous vehicle platforms is also vital.

- End Users (Drivers):

Characteristics: End users, such as drivers, benefit from road sign detection through ADAS features. They require user-friendly interfaces and alerts that provide timely and accurate information about detected road signs. The system should be intuitive and not cause distractions while driving.

2.5 Operating Environment

SafeDrive for smartphones will utilize the device's camera to capture real-time images or video streams of the road ahead. These visual inputs will be processed through deep learning models, such as NAS-YOLO, YOLOv7, or YOLOv8, which have been fine-tuned for road sign recognition. The app will analyze the frames to identify and classify road signs present in the field of view, considering factors like lighting conditions and environmental variables. Once detected, the app will overlay informative labels or notifications on the screen, providing drivers with timely and accurate information about the detected road signs, helping them navigate safely and adhere to traffic regulations. Users can access the app through an intuitive mobile interface, making it a practical and user-friendly tool for enhancing road safety on their smartphones.

2.6 Design and Implementation Constraints

1. Computational Resources:

Constraint: Limited computational power on mobile devices for real-time processing.
Research Paper: Discuss the optimization techniques and model architectures employed to make the models computationally efficient for mobile devices.

2. Data Availability:

Constraint: Limited diversity in the road sign dataset from Kaggle.
Research Paper: Highlight any dataset limitations and discuss strategies used to mitigate dataset biases or augment the dataset for better model generalization.

3. Environmental Variability:

Constraint: Varying lighting and weather conditions affect road sign visibility.
Research Paper: Present findings on how the models perform under different environmental conditions and discuss strategies for handling such variability.

4. Model Generalization:

Constraint: Models may not generalize well to regions with different road sign designs or standards.
Research Paper: Address the challenges of model generalization and provide insights into potential adaptation methods for different regions.

5. Real-time Processing:

Constraint: Real-time processing requirements for road sign detection in mobile applications.
Research Paper: Describe the techniques used to optimize model inference for real-time performance and discuss any trade-offs made.

6. Hardware Compatibility:

Constraint: Compatibility issues with certain smartphone models or operating systems.
Research Paper: Discuss the compatibility challenges and solutions, along with recommendations for hardware and software configurations.

2.7 User Documentation

- Ease of Use: User documentation provides clear instructions on how to install, configure, and use the road sign detection application effectively. This ensures that

users, including drivers and system administrators, can quickly and confidently utilize the application without encountering usability issues.

- Maximizing Benefits: Proper documentation helps users make the most of the application's features and capabilities. Users can learn about all available functionalities, such as customization options, alerts, and user interface features, enabling them to optimize their experience.

- Troubleshooting: Inevitably, users may encounter issues or have questions about the application. User documentation includes troubleshooting guides that address common problems and provide solutions, reducing user frustration and support requests.

- Safety and Accuracy: In the context of road safety, clear documentation is critical to ensuring users fully understand how the application works and the accuracy of its road sign detection. This promotes safe driving practices and compliance with traffic regulations.

2.7 Assumptions and Dependencies

- Assumptions:

Definition: Assumptions are statements or conditions that are accepted as true, without proof or confirmation, for the purpose of planning and executing a project.

Purpose: Assumptions provide a basis for project planning but can introduce risks if they turn out to be incorrect. They help project managers make decisions and allocate resources based on certain expectations.

Examples:
If the selected deep learning models (NAS-YOLO, YOLOv7, YOLOv8) will perform well on the road sign detection task based on prior research.
If the dataset obtained from Kaggle accurately represents the diversity of real-world road sign scenarios.

- Dependencies:

Definition: Dependencies are relationships or connections between project tasks or elements where the completion or progress of one task is reliant on the completion or progress of another.

Purpose: Identifying dependencies is crucial for project scheduling and resource allocation. It helps ensure that tasks are completed in the correct order and that delays in one task don't cascade into delays in others.

Examples:
The training of deep learning models is dependent on data preprocessing, which must be completed before model training can begin.
The research paper's completion depends on the availability of accurate results from model evaluation and analysis.

3 System Features

3.1 User Registration and Authentication

3.1.1 Description: This feature enables users to create accounts, log in, and reset their passwords. It is of High Priority as it forms the foundation for user interactions on the platform.

3.1.2 Stimulus/Response Sequences

1. **User Registration:**
    - Stimulus: User navigates to the registration page and provides valid registration details.
    - Response: System validates the information, creates a new account, and provides a success message.
2. **User Login:**
    - Stimulus: Registered user provid
    - es valid login credentials.
    - Response: System verifies the credentials, grants access, and redirects the user to their profile page.
3. **Password Reset:**
    - Stimulus: User initiates a password reset request by providing their email address.
    - Response: System sends a password reset link to the user's email. Upon clicking the link, the user can reset their password.

3.1.3 Functional

- Road Sign Detection:
  The system shall accurately detect and classify various types of road signs, including regulatory, warning, and informational signs, in real-time.
- Multi-Platform Compatibility:
  The system shall be compatible with multiple platforms, including mobile devices, embedded systems, and in-vehicle displays.
- Real-Time Processing:
  The system shall process input data from cameras or sensors in real-time, with minimal latency, to ensure timely road sign recognition.
- Alerting Mechanism:
  The system shall provide an alerting mechanism to notify the driver or relevant authorities when a critical road sign is detected.
- Customization:

Users shall have the ability to customize the system for specific regions, languages, or unique road sign requirements.

- User Interface:
  The system shall feature a user-friendly interface for configuring model parameters, viewing detection results, and accessing system logs.
- Data Logging and Reporting:
  The system shall log, and report detected road signs and their locations to support traffic analysis and reporting.
- Offline Mode:
  The system shall offer functionality to operate in offline mode, ensuring it works even without a continuous internet connection.
- Accessibility:
  The system shall include accessibility features to ensure it can be used by individuals with disabilities.
- Multi-Region Support:
  The system shall be capable of recognizing and displaying road signs according to the region or country in which it is deployed.
- Cross-Platform Compatibility:
  The system shall ensure cross-platform compatibility, allowing users to access it from various devices and operating systems

3.2 Application Update

- Regular Maintenance: Establish a routine maintenance schedule to address bug fixes, security updates, and performance enhancements to keep the application up to date.
- Version Control: Implement version control practices to track changes, manage updates, and maintain a clear history of application revisions.
- Automated Updates: Offer automated update mechanisms for users to easily install the latest application versions, ensuring they benefit from improved features and security.
- User Feedback Integration: Incorporate user feedback channels within the application to collect input on areas that require updates, ensuring a responsive and user-driven update process.
- Regression Testing: Conduct thorough regression testing after each update to verify that new features do not introduce issues and that the application remains stable.

3.3-High Accuracy.

- Accuracy Metrics: Define and track accuracy metrics to measure the performance of the road sign detection models, ensuring high precision and recall rates in detecting road signs.
- Robustness Testing: Conduct rigorous testing under various conditions, including challenging lighting and weather scenarios, to validate the models' ability to maintain accuracy.
- Adaptive Algorithms: Implement adaptive algorithms that continuously learn from real-world data to improve detection accuracy and reduce false positives.
- Alerting Mechanism: Develop an effective alerting mechanism that not only detects road signs but also provides timely alerts to drivers or relevant authorities to prevent accidents.
- Safety Evaluation: Regularly evaluate the impact of the application on road safety by analyzing accident data and assessing how the system's accuracy contributes to accident prevention.

3.4 Real-time processing

- Latency Targets: Set specific latency targets for real-time processing and continuously monitor and optimize the system to meet these targets.
- Parallel Processing: Employ parallel processing techniques to distribute computational tasks efficiently across hardware resources, ensuring minimal latency.
- Edge Computing: Implement edge computing capabilities to perform real-time processing on local devices, reducing reliance on external servers and latency.
- Load Balancing: Utilize load balancing mechanisms to evenly distribute processing loads across server clusters, preventing bottlenecks during peak usage.

4 External Interface Requirements

4.1 User Interfaces

The user interface (UI) of our road sign detection system is meticulously designed to provide an intuitive, user-centric experience. Its responsive layout adapts seamlessly to various devices, ensuring accessibility for all users. Visual clarity and feedback mechanisms enhance usability, while customizable options cater to individual preferences. Interactive maps and multilingual support offer additional user-friendly features, and offline functionality ensures reliable operation even in low-connectivity areas. Security measures, error handling, and user support features contribute to a well-rounded UI that prioritizes user satisfaction and effective road safety enhancement.

4.2 Hardware Interfaces

In our road sign detection project, hardware interfaces play a pivotal role in facilitating the seamless interaction between our software components and the physical devices responsible for data acquisition and processing. These hardware interfaces encompass various critical aspects. We integrate with a diverse range of cameras, both onboard and external, as well as other sensors to capture real-time images and video streams of the road environment. Compatibility with various camera models and configurations is essential to ensure flexibility in deployment.

4.3 Software Interfaces

Software interfaces play a fundamental role in orchestrating the interaction between our deep learning models, data processing modules, and the broader software ecosystem. These software interfaces encompass several essential elements. Firstly, our models are integrated into the software architecture through well-defined APIs, enabling seamless communication and data exchange. Compatibility with popular deep learning frameworks such as TensorFlow and PyTorch ensures flexibility and accessibility for developers. Additionally, data preprocessing and augmentation modules are integrated to enhance the quality of input data before model inference, optimizing detection accuracy. Our software interfaces also include communication protocols and APIs for data transmission and synchronization, allowing for real-time updates and integration with traffic management systems. Moreover, our user interfaces, whether on mobile devices or in-vehicle displays, are thoughtfully designed to provide a user-friendly experience, with intuitive controls and responsive layouts. In summary, our robust software interfaces enable the efficient operation and integration of our deep learning models, ensuring accurate and real-time road sign detection while promoting accessibility and usability for end-users.

4.4 Communications Interfaces

We prioritize data security by implementing secure communication channels with encryption and authentication mechanisms to safeguard sensitive information. In summary, our communication interfaces form the backbone of our road sign detection project, enabling data flow, integration, and security for reliable and efficient road sign recognition and enhanced road safety.

5 Other Nonfunctional Requirements

5.1 Performance Requirements

In our road sign detection project, stringent performance requirements are paramount to ensure accurate and real-time road sign recognition. The system must achieve a response time of less than 100 milliseconds for detecting and classifying road signs, enabling rapid decision-making for drivers and autonomous vehicles. Additionally, the system should be able to handle a high volume of concurrent requests without compromising its real-time processing capabilities. To meet these demands, we employ state-of-the-art deep learning models and optimize them for efficiency, utilizing hardware acceleration where necessary. Regular performance testing and monitoring are integral to maintaining these requirements, ensuring that our system consistently delivers fast and reliable road sign detection, even under varying environmental conditions.

5.2 Security Requirements

Security is a paramount concern in our road sign detection system. To safeguard user data and maintain the integrity of the system, we implement rigorous security requirements. Data encryption mechanisms are employed to protect user data during transmission and storage. Robust authentication and authorization systems are in place to ensure that only authorized users can access sensitive functionalities. Furthermore, we conduct regular security audits and vulnerability assessments to identify and mitigate potential threats. Compliance with data privacy regulations is strictly adhered to, and measures such as anonymization and pseudonymization of personally identifiable information (PII) are implemented to protect user privacy. Our commitment to security ensures that the road sign detection system remains a trustworthy and secure tool for users.

5.3 Software Quality Attributes

Our road sign detection system is built with a focus on various software quality attributes that contribute to its robustness and reliability. Usability is a key attribute, with an intuitive user interface designed for easy interaction and accessibility features

to accommodate users with disabilities. Reliability is achieved through fault tolerance mechanisms that enable the system to continue functioning in the event of hardware or software failures. Scalability ensures that the system can seamlessly accommodate increasing user loads and adapt to various hardware platforms. Maintainability is a priority, with a modular codebase and comprehensive documentation for easy updates and troubleshooting. Moreover, performance optimization and regular testing are integral to ensuring that the system consistently meets its response time requirements. These software quality attributes collectively enhance the overall effectiveness and user experience of our road sign detection solution.

6 Other Requirements

6.1 Database Requirements

- Effective data management is a cornerstone of our road sign detection system, and as such, we have established specific database requirements to ensure seamless storage, retrieval, and management of critical information.
- Our system relies on a robust and scalable relational database system capable of efficiently storing metadata related to road signs, detection timestamps, and geographic coordinates.
- Additionally, our database is designed to facilitate fast querying and retrieval of historical road sign data, supporting data analysis and traffic management needs.
- We prioritize data security and implement access controls, encryption, and regular backups to protect sensitive information.
- Compliance with data privacy regulations is maintained through data anonymization and pseudonymization practices, ensuring that user privacy is safeguarded.
- With these database requirements in place, we are equipped to handle large volumes of data while ensuring its integrity, security, and accessibility.

6.2 Performance Optimization

- Performance optimization is a foundational aspect of our road sign detection system, enabling rapid and reliable road sign recognition. To achieve optimal performance, we employ several strategies.
- First and foremost, our deep learning models are meticulously optimized to maximize inference speed while maintaining accuracy. Hardware acceleration, such as GPUs, is leveraged to expedite model execution.
- Additionally, we implement caching mechanisms to store frequently accessed data, reducing redundant processing and improving response times. Load balancing and horizontal scalability are used to distribute processing loads effectively, ensuring that our system remains responsive even under high traffic conditions.
- Regular performance testing and monitoring are conducted to identify bottlenecks and fine-tune system parameters.
- By prioritizing performance optimization, we guarantee that our road sign detection system consistently meets response time requirements, enhancing road safety for all users.

DOCUMENTATION ENDING