Signa: Enhancing Priority, Speed, and Pedestrian Sign Learning with Image Recognition and Auditory Feedback

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Chapter 1

Introduction

Transportation safety is a paramount issue in today's world where road accidents and traffic offenses constitute a serious challenge to society. As per, Robielos et al. (2022) emphasized the poor understanding of traffic signs has resulted in serious hazards, posing an important issue in many countries. In Metro Manila, non-compliance with traffic signs was the cause of 27.65% of accidents and violations, which was the top reason for such occurrences.Additionally, Aguilar and Recario (2023) state that road traffic accidents are among the leading causes of death worldwide, with most incidents resulting from driver error and inadequate knowledge of traffic signs. Road traffic accidents are a major public health issue. Thousands of Filipinos die or are killed each year as a result of traffic accidents (Golden Future, 2024).

Road traffic accidents are on the rise in the Philippines. According to the Philippine Statistics Authority (2024), road traffic accidents are the 12th most common cause of death in the country. Therefore, educational driving tools are pivotal to help the license and starting drivers to understand and retain the driving protocols; especially the major traffic signs. Based on the findings, AI offers significant benefits, including personalized learning, improved academic outcomes, and enhanced student engagement (Vieriu et al. 2025). Utilizing its capacities enables students to have more engaging and dynamic learning experiences. By integrating AI-powered learning instruments, prospective and qualified drivers are better able to understand and retain major traffic rules, especially crucial traffic signs. Whereas, efficient traffic control is essential for guiding and informing drivers using vehicular signals (Duque et al. 2023).

The evolution of technologies, including computer vision and machine learning, provides viable solutions to increase driver alertness and minimize road risks. The YOLOv11's novel architecture utilizes sophisticated feature extraction methods, enabling more subtle detail capture with fewer parameters. This leads to better accuracy in a wide variety of computer vision (CV) applications, Khanam et al. (2024). Therefore, Signa is a product built with this intention, to ensure precise detection of priority, speed, and pedestrian signs. Signa is an educational software aimed at assisting drivers in memorizing essential traffic sign information for enhanced real-road recognition and response. By embedding traffic sign literacy, it becomes safer, the probability of accidents decreases, and responsible driving habits are encouraged.

Purpose and Description

The Signa is developed to be an innovative educational traffic sign detection software embedded with real time auditory guidance to boost driving literacy and safety through the application of advanced computer vision algorithm. The implementation of the YOLO model, delivers accurate recognition of critical traffic signs, which include priority, speed limit, and pedestrian markers.

The system is built on a robust foundation of preprocessed and augmented dataset; important for model training and tuning.

Utilizing high-resolution image analysis powered by the YOLOv11, Signa intelligently identifies critical road signs, including priority, speed limits, and pedestrian markers, with exceptional accuracy. Developed for efficient learning into transportation systems, the software enhances road safety through an intelligent auditory alert mechanism, offering real-time notifying drivers upon sign detection. By pushing the boundaries of image-based recognition, this innovation sets a new standard for enhancing transportation literacy and intelligent road navigation

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Statement of the Problem

Numerous incoming license drivers struggle with identifying and understanding the lessons in driving schools about transportation, mainly traffic signs. According to Fernandez et al. (2020), drivers showed low comprehension of traffic signs, with the yield sign correctly identified only 41.67% of the time and speed limit signs at 37.62% accuracy. Despite an overall average accuracy of 76.25%, the 19.86% error rate per sign highlights gaps in knowledge. These findings underscore the need for better educational tools like Signa to improve traffic sign comprehension. Which can lead to unsafe driving behaviours and the difficulty to pass licensing exams.The usual traditional learning methods often rely on static materials such as manuals and classroom instruction, which may not be engaging or effective for long-term retention. The lack of interactive and adaptive learning tools makes it challenging for learners to grasp essential traffic rules, increasing the risk of road accidents.

In spite of having obtained a driver's license, a large majority of drivers are not able to maintain the ability to consistently recognize traffic signals during actual driving. This insufficiency is attributed to the instructional method, mainly focused on text manuals and passive audio communication with instructors, which fails to adequately develop practical skills. The disparity between theory and practice creates delayed or faulty responses to traffic signs, and hence the chances of traffic offense and accidents increase.

The breakthroughs in computer vision and deep learning in the field of AI provides a potential to enhance traffic sign recognition for driving education. However, there is still a lack of tools that incorporate multisensory learning, including the integration of visual recognition with auditory signals. Introducing auditory feedback in the form of voice-guided explanations or real-time notifications can complement visual signals, enhance understanding, and enable drivers to respond more precisely to traffic signs.

Research Objectives

The lack of innovative techniques in the domain of transportation results in low retention and comprehension of traffic signs and driving precautions. This study attempts to create an accurate deep learning architecture that integrates real-time audio feedback and image processing techniques to enhance the reading and comprehension of traffic signs. By training and validating the architecture using real-world data sets, the effectiveness and efficiency of the model will be determined in terms of key classification metrics. Further, the impact of improved traffic sign literacy on driving behavior and road safety will be useful insight in terms of its real-world application.

Thus, the specific objectives of the research are:

- To collect traffic sign data that impact the accuracy of model
- To develop a deep learning model with auditory feedback for transportation literacy
- To evaluate the accuracy and reliability of the YOLOv11 model

Significance of the Study

The rapid growth of incoming student drivers, studying for licensure exams and retaining knowledge increases at all times.Therefore, Signa provides a modern and interactive approach to learning traffic signs, benefiting:

New Drivers and Learners

The rise of technology in the field of education is proven to help the students to effectively learn the information at a faster and efficient rate. Combining the powerful ability of AI to detect the traffic signs and immersive capacity of the system to create auditory assistance for identifying the image. Helps the new drivers and learners to retain information and knowledge.

Transportation Sector

Leveraging the capacity of AI to help the organization, government and private sectors allows its traditional method of teaching to grow into immersive and expansive. The creative approach allows the company to help the learners to effectively maintain the knowledge learned from the institution

Future Researchers

The study provides a solid framework for future researchers that focuses on computer vision, deep learning, and transportation education. Future researchers can build upon the system's methodologies and findings to further advance traffic sign detection systems and explore new innovations in transportation safety.

Scope and Limitations

Signa focuses specifically on detecting priority, speed, and pedestrian signs using the YOLO model. The system is designed for integration with auditory alerts, providing real-time information retention. The study primarily evaluates the system’s performance under day conditions. However, the scope is limited to specific type images of traffic signs, environment and weather conditions, due to the limited computing capacity to train models.

Moreover image processing techniques and edge detection are the primary function to predict certain traffic signs. Future enhancements could include expanding the sign detection range and improving performance in challenging environments.

Chapter 2

Review of Related Literature

To shed light on the importance of computer vision and in detecting traffic signs using the YOLO model, several studies were reviewed:

Significance of Traffic Signs

Traffic signs are important to maintain the safety of vehicles and pedestrians in the road. It serves as a floating guide to help drivers to be cautious and aware of the state of the route (Sanchez, 2022). According to Navarro et al.(2022), stop signs are pivotal in controlling traffic at intersections, warning drivers to halt and assess the situation before proceeding. Thus, it reduces the likelihood of collisions. Moreover, another priority sign; yield or give way to oncoming traffic is essential for road safety. Yield signs, clearly positioned at intersections and entry points, direct drivers to reduce speed and give way to vehicles or pedestrians with the right-of-way before continuing (Yazdi, 2024). Together with pedestrian crossing signs, they are vital components of urban traffic management, significantly enhancing pedestrian safety and reducing accidents.

Road traffic signs and symbols can be very helpful in assisting motorists and pedestrians. It will provide drivers enough and valuable information as they travel on the road to keep them aware of certain road conditions and limitations (Ningal and Onos, 2021). Consequently, Arhin et al. (2021) discovered enhanced signs have improved driver compliance with pedestrian right-of-way laws, leading to safer crossing environments and improved flow. As stated by Walker (2025), Wales' implementation of a default 20 mph speed limit on urban roads had a significant impact. Within the first year, this measure resulted in approximately 100 fewer fatalities or serious injuries, demonstrating the effectiveness of reduced speed limits in enhancing road safety.

AI and Auditory Feedback in Driver Education

The vast capabilities of AI in society is impeccable, it leverages the scale of computing capacity efficiently and allows less human intervention (DTI, 2024). In the field of education, it transforms traditional learning into an engaging experience; assisting the students to be more productive and retain the knowledge. Notable example is the artificial intelligence integration in Philippine education, such as DepEd’s collaboration with Microsoft M365 Copilot, helps automate lesson planning and grading, saving teachers up to 20 hours per week. This allows educators to focus more on student engagement and personalized instruction (Microsoft, 2025). Moreover, AI-powered platforms can analyze student performance and adjust lesson difficulty accordingly, ensuring that each learner progresses at an appropriate pace. This adaptability addresses diverse learning styles more effectively than traditional methods (Wagenaar, 2025).

Lin et al. (2024), state that artificial intelligence applications augment creativity by offering novel ideas and streamlining problem-solving mechanisms through immersive features, as well as emotional well-being through gamification methods. In addition, empirical evidence supported that both educators and students have positive perceptions about its benefits. Thus, capitalizing on the growing field of AI enables to increase exponentially the skills and understanding of certain topics.

Another study investigated the effects of combining auditory messages with traffic signs in partially automated driving. The results suggest that adding audio messages helps drivers process traffic sign information more effectively and maintain higher alertness and safety during driving (Pi-Ruano et. al., 2024). Thus, highlighting the importance of an effective model for driver's education with sound feedback.

YOLO Model Architecture

From the study of Khan et al. (2023), deep neural networks have achieved impressive results in various applications, including object identification and automatic recognition of traffic signs. Based on the study of Selçuk et al.(2023), YOLOv4 achieved a 98% accuracy rate surpassing Faster R-CNN and SSD in both speed and precision. Their findings highlighted the efficiency of deep learning models in real-time traffic sign detection, making them suitable for applications in driver assistance systems.

In their research, Hernandez et al. (2023) developed an application designed for traffic sign detection, using YOLOv5. The study demonstrated the effectiveness of integrating deep learning. While their study shows promising results, we sought to further improve the traffic sign detection by leveraging the more robust YOLOv11.

Building upon these studies, Pavani et al. (2024) proposed a traffic sign detection and recognition system by leveraging CNN algorithm. Their approach emphasizes accurate classification and feature extraction, which aligns with efforts to improve detection performance across varying environments. This aligns with the study's goal of enhancing traffic sign recognition by focusing on deep learning-based methods for improved detection accuracy. While many studies emphasize prediction, the Signa focuses on image detection with audio feedback, demonstrating the effectiveness of deep learning in traffic sign recognition in educational settings.

Given the success of YOLO-based approaches in traffic sign detection, this study aims to apply YOLOv11 for accurate traffic speed limit detection. By leveraging CUDA GPU, the system will ensure accurate and efficient identification of speed limit signs, even under varying environmental conditions. Through this research, we aim to contribute to educational initiatives on traffic safety by improving awareness and understanding of speed limit signs, ultimately supporting automated traffic monitoring and safer road navigation.

Hypothesis

LOCAL LITERATURE

Related Study/ Technique(s) used	Goal	Similarities	Differences
Aguilar & Recario (2023)	Identifying driver errors and lack of traffic sign knowledge as major contributors to road accidents.	Emphasizes the need for improved driver education on road safety.	Highlights the used different programming language such as Java
Hernandez et al. (2023)	Implementing YOLOv5-based traffic sign detection	Implementing deep learning techniques in traffic sign detection.	Uses the older YOLOv5 whereas this study uses a newer YOLOv11.
Robielos et al. (2022)	Analyzing the traffic sign comprehension on road safety in Manila	Focuses on traffic sign awareness and literacy in reducing accidents	Focuses on traffic sign violations rather than AI-driven solutions.
Golden Future (2024)	Discuss the accident rate and deaths of Filipinos. Also the contributing factors of such accidents	A link between road accidents and the pressing need to create educational driving software	Focus on analyzing the elements that causes the accidents to the roads
Ningal et al. (2021)	Established the traffic education and road safety to prevent accidents	Create a strong foundation into transportation education	Focuses into educational side of basic road safety and accident awareness
Fernandez et al. (2020)	Discuss the importance of traffic signs to the drivers in city of Manila	Development and study to improve traffic sign literacy	Concentrates into literary side and statistical information of the traffic sign comprehension
Sanchez (2022)	Explores the importance of traffic lights and road signs	Traffic sign literacy and information to the public	Emphasizes the discussion of traffic law and order
DTI (2024)	Innovate the Philippine landscape using AI	Development of revolutionary strategy and software to help the field of research	Review of the general AI plans into number of fields
Duque et al.(2023)	Assess the	Provides	Provides journal study

	understanding the traffic control devices in of drivers in Tuguegarao road	developmental knowledge into transportation field	about the demographics of drivers and licensing
PSA (2024)	Reports the statistical analysis of the transport accidents between January to December 2023	Provides information about the connection of road accidents and urgency to develop educational driving software to reduce the rate of accidents	Discuss only the statistical viewpoint of of the accident rates in the country
Wagenaar (2025)	Discuss the role of artificial intelligence into personal learning	Emphasizes personalized AI system for education	Overview of the benefits, challenges and conclusion of personalized AI

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Related Study/ Technique(s) used	Goal	Similarities	Differences
Khan et al. (2023)	Recognize and classify road signs in urban areas	Developing CNN model for traffic sign recognition	Utilizes R-CNN models to predict the data
Arhin et al. (2021)	Study the effectiveness of modified pedestrian crossing signs	Showcases different varieties of traffic signs and increasing knowledge into transportation literacy	Only focuses on pedestrian crossing signs rather than detecting various traffic signs and integrating auditory feedback
Navarro et al. (2022)	Proving the effectiveness of traffic signs in transportation	Emphasizes on transportation safety, mainly in traffic signs.	Scholarly research about the simulation of controlled intersection trajectories
Lin et al. (2024)	To explore the effects	Integrating AI in	The study focuses on

	of AI in education and its advantages to the society	learning to increase information retention	general education rather than driving education and detection.
Khanam et al. (2024)	Analyzing the YOLOv11's performance improvements and architecture	Highlights advancements in YOLOv11's feature extraction and efficiency.	The study focuses on the structural analysis rather than detection and application in traffic sign detection
Pavani et al. (2024)	Develop a CNN-based traffic sign detection.	Emphasizes feature extraction and classification to develop deep learning model.	Study does not contain auditory feedback in traffic sign detection for better understanding.
Pi-Ruano et al. (2024)	Investigate the auditory feedback in driving	Highlights the improved driving safety through auditory feedback	The study does not employ the use of the YOLO algorithm or deep learning for traffic sign detection.
Selçuk et al. (2023)	Evaluate the effectiveness of YOLOv4 in traffic sign detection	The use of deep learning in traffic sign detection	The study did not integrate auditory feedback and uses older YOLOv4 for detection.
Vieriu et al. (2025)	To assess the effects of artificial intelligence on learning tools	Explores the advantage of AI in enhancing learning experiences	The study focuses on general education rather than AI and driving education
Walker (2025)	Assessing the impact of the 20mph speed limit in Wales.	Focuses on road safety through regulatory measures	It only studies speed limits rather than integrating AI powered detection systems.
Yazdi (2024)	Studies the Importance of yielding to oncoming traffic	Developing the road safety and awareness to the public	It only studies traffic yielding and does not integrate AI and detection.
Microsoft (2025)	Leverage the	Development and	Emphasize report of

	adoption of AI into Philippine education	usage of AI system to increase the efficiency of learning	expansion of technological systems

Chapter 3

METHODOLOGY

This chapter highlights the methods and processes used to develop the Signa software

Research Design

The research employs a descriptive quantitative approach to evaluate user feedback on Streamlit web application designed to predict traffic signs using an YOLOv11 model. The study systematically collects image data through the Roboflow universe and personal data of the researchers, to properly evaluate the training of computer vision model. The dataset is open-source and copyright-free, hence meeting the requirements of ethical research. The researchers also possess as primary data the image annotations that were carefully chosen to train and test the computer vision model. The dataset is crucial in determining the effectiveness of the YOLOv11 model in detecting traffic signs in various conditions, hence ensuring the reliability and accuracy of the web application.

In addition, the study also focuses on the assessing of the features for the prediction of traffic signs. To further determine the model optimization and increase their predictive potential, the study also investigates deep learning parameter tuning strategies, which will eventually increase the system's efficacy.

Sampling

The gathering of data was a combination of primary and secondary sources. The roboflow universe, an open-source and public domain source of number of images for training takes half of the data, whereas the primary source are the images from dash cams and images in the public roads and highways. The union of two datasets provides a wide range of information and generalization capacity of the model to predict various instances of images.

In addition, the study focuses on four specific traffic sign classes: child-pedestrian crossing, give way, speed limit, and stop signs. The dataset is structured as follows: child-pedestrian crossing (150 images), give way (150 images), speed limit (350 images), and stop sign (150 images). Note that the speed limit category has a greater number of images (350) compared to the others. This is because there are different numerical values placed on speed limit signs (e.g., 30, 40, 60, 80 km/h), and hence a more heterogeneous dataset will be required to ensure the model is able to adequately discriminate between them. By using a balanced dataset but taking into account the heterogeneity implied in the speed limits signs, the training process delivers strong detection and classification accuracy for all the traffic sign categories specified.

Furthermore,To train and evaluate the YOLOv11 model, the dataset is divided into 89% training split (1,077 images), 6% validation split (78 images), and 4% test split (53 images). Various data preprocessing and augmentations are used to increase the model's generalization and robustness.

Auto-orientation and resizing all images to 640×640 pixels are applied as preprocessing. The augmentations generate three versions of each training example, such as horizontal and vertical flipping, 90° rotation (clockwise, counterclockwise, upside down), brightness shifting (-20% to +20%), blur (up to 2.5px), and noise injection (up to 0.1% of pixels). These augmentations expose the model to various conditions, hence making it more capable of detecting and classifying traffic signs in real-world applications.

Instruments and Materials

The tools for data collection includes Roboflow Universe, a website for copy-right free pictures for training computer vision models, dash cams and camera to capture the images to create the dataset. The diverse and varying sources of input were extensively experimented to ensure a well-rounded dataset, optimizing the model's ability to generalize properly. Furthermore, the instruments utilized for analysis and prediction includes the YOLOv11 model, a powerful Pytorch CNN architecture which is able to capture pattern and edge detections. Streamlit, a data science-focused web application for online deployment. For the libraries, python language is used to program and pygame to initialize audio feedback of prediction.

Model Features and Parameter Tuning

The YOLO model ("yolo11m.pt") is parameter-optimized to improve its accuracy, efficiency, and stability. The model is trained for 50 epochs with AdamW optimizer and learning rate of 0.0005 to enable controlled and balanced learning. A batch size of 4 is used to limit GPU usage, while an image size of 640 is used to detect objects in detail. To improve generalization, dropout (0.2) is used, and data augmentation techniques such as flipping (horizontal and vertical) and mosaic transformations (0.3) are used in order to expose the model to diverse data. Stability parameters such as patience (10 epochs), warmup (3 epochs), and weight decay (0.0005) avoid overfitting and enable smooth convergence. Performance tuning parameters such as Automatic Mixed Precision (AMP), limited worker threads (2), and disabled caching are used to limit GPU memory usage while preserving accuracy.

These tuning decisions affect the performance of the model in several ways. The low batch size ensures that learning is stable even on low computational power hardware, and the learning rate keeps the model from making excessively large corrections that destabilize learning. The AdamW optimizer enhances weight updates to converge faster and more accurately. Dropout and augmentation enhance the robustness of the model to real-world variability in traffic signs, enhancing its generalization from training data. Stability parameters such as patience and warmup avoid early stopping or sudden loss of accuracy.

In summary, setting appropriate parameters based on the based-model's issue is important. Finding equilibrium to the between the complexity and generalization capability are essential to the success of deep learning model

Data Collection Procedures

The acquisition of images for construction of the computer vision dataset was carried out systematically to obtain a well-defined and consistent quantity of data. The project begins with a clear definition of road signs that were to be of primary concern in the model predictions, in accordance with the objective of the research to improve recognition of traffic signs to improve road safety. The foundation of selection had the objective to prioritize signs of vehicular movement, which were of great concern to learner and novice drivers. This is for the sake of ensuring that required signs that govern driving behavior and decision-making have been incorporated.

For this, the dataset utilized four primary classes of traffic signs: Child-Pedestrian Crossing (150 images), Give Way (150 images), Speed Limit (350 images), and Stop Sign (150 images). The class Speed Limit contains the largest number of images (350) because of its highest priority in traffic control and the diversity of speed limit values for different road conditions. The Child-Pedestrian Crossing sign enables cars to expect pedestrian traffic in school areas and pedestrian movement-heavy areas. The Give Way sign facilitates correct yielding practice at intersections to prevent accidents. The Stop Sign requires stopping the car at critical intersections, improving road manners. By acquiring images of these signs in a systematic manner under different lighting and environmental conditions, the dataset is strong and accurate in real-world detection, advancing the objective of the study in creating an efficient traffic sign detection system.

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