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Deep Learning-Based Framework For Robust Traffic Sign Detection Under Challenging Weather Conditions

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Abstract:
Thanks to the rapid development of computer vision and deep learning technologies, advanced driver assistance systems (ADAS) have recently become widespread. These systems aim to increase driving safety and reduce the number of traffic accidents. Modern cars usually have ADAS systems integrated into their electronics, but other vehicles do not have such an integrated system. This paper presents a portable and image-based ADAS system for real-time detection of traffic signs, vehicles, and pedestrians. To realize real-time detection, the developed system uses the YOLO v5 algorithm. This single-stage detector is very popular as it has high detection speed and accuracy. The model was trained on the study-specific datasets to analyze the developed system. Then, the implementation metrics were calculated to evaluate the training and testing performances of the model. In addition, the model was compared in low-power, high-performance embedded platforms and in a computer to measure the real-time performance. Considering the excellent accuracy and high speed, this study will guide researchers in demonstrating the efficiency and suitability of real-time road object detection with YOLO v5 on mobile platforms.

Index Terms: Deep Learning, LSTM, real-time, TSDR, ADAS, Neural Networks, YOLOv5

1. INTRODUCTION

As the population continues to grow, the number of vehicles on the roads is increasing at a rapid pace. This surge in traffic volume inevitably leads to a higher risk of accidents and fatalities. Various factors such as drowsiness, fatigue, and road conditions contribute to these risks. To address this issue, numerous studies and solutions have been developed over time to mitigate accident risks and enhance driving safety.

The advancements in technology have played a crucial role in the development of systems aimed at improving driving safety. These technologies collectively form the infrastructure of Advanced Driver Assistance Systems (ADAS) and autonomous driving systems. ADAS systems are designed to assist drivers and vehicles in detecting and responding to dangerous traffic situations accurately and promptly. They have become a significant area of research and development, driven by the need to enhance safety and comfort in the automotive industry.

The development of ADAS systems incorporates various technologies. Among these, camera-based solutions offer notable advantages, including cost-effectiveness. With the rapid advancements in computer vision technologies, processing and analyzing images from cameras have become increasingly efficient and accurate.

Beyond the vehicle itself, ADAS systems also involve external environment sensing, which entails gathering information about the surrounding driving environment. This information encompasses nearby vehicles, pedestrians, traffic signs, traffic lights, and certain objects. However, the quality of environmental information perception can be influenced by external factors such as weather conditions, road conditions, and lighting conditions. Consequently, these factors need to be taken into consideration during the design and development of ADAS systems.

In summary, the rising number of vehicles on the road poses increased risks of accidents and fatalities. ADAS and autonomous driving systems have emerged as essential solutions to address these risks. Camera-based solutions, leveraging computer vision technologies, offer cost advantages and efficient image processing capabilities. Furthermore, the design of ADAS systems must account for external factors that affect the perceptual quality of environmental information, such as weather, road conditions, and lighting.

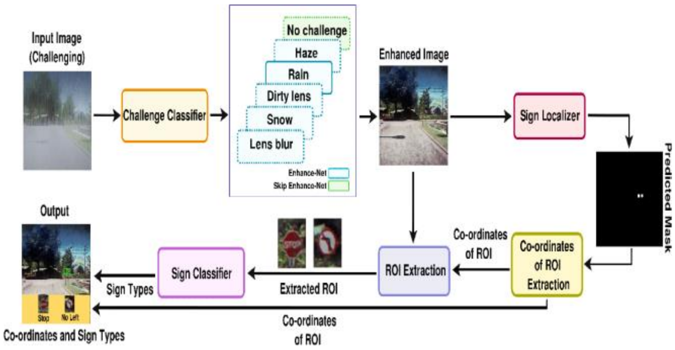

Fig 1 Example Figure

The growing population has led to an increase in vehicles on the roads, resulting in a higher risk of traffic accidents and fatalities due to factors like drowsiness and road conditions. To mitigate these risks, there has been significant research and development in Advanced Driver Assistance Systems (ADAS) and autonomous driving. ADAS systems assist drivers in identifying and responding to dangerous situations promptly. Camera-based solutions in ADAS offer cost advantages and benefit from advancements in computer vision. They enable object recognition, lane detection, and traffic sign identification, improving decision-making and providing timely warnings. Additionally, camera-based ADAS systems provide a comprehensive view of the driving environment, enhancing situational awareness. These systems have the potential to enhance safety, reduce accidents, and improve the driving experience through timely detection and response to dangerous traffic situations.

2. LITERATURE REVIEW

Technical feasibility of advanced driver assistance systems (ADAS) for road traffic safety:

This paper explores the technical feasibility of five Advanced Driver Assistance System (ADAS) functions to contribute to road traffic safety, to reach stated European (EU) and national road traffic safety targets. These functions – enhanced navigation, speed assistance, collision avoidance, intersection support and lane keeping – were selected from previous research as adequate substitutes for infrastructure related measures. State-of-the-art enabling technologies (like positioning, radar, laser, vision and communication) and their potential are analysed from a technical perspective, and possible obstacles for large-scale dedicated ADAS implementation for road traffic safety are discussed.

Design of efficient embedded system for road sign recognition:

Automatic traffic sign recognition enhances driver interactivity while driving. It improves the vigilance of the driver by alarming-him/her of signs that he/she may not perceive. In this paper, an embedded real-time system for automatic traffic sign recognition is proposed. The segmentation task of an acquired scene is processed in the HSV color space. The recognition process is performed by using the Oriented fast-and-Rotated Brief features. The developed algorithm is implemented on a ZedBoard hardware platform. The detection rate reaches the value of 97.39%. The recognition rate is equal to 95.53%.

An enhanced framework for multimedia data: Green transmission and portrayal for smart traffic system:

The object tracking in video surveillance for intelligent traffic handling in smart cities requires an enormous amount of data called big data to be transmitted over the network using the Internet of Things. Manual monitoring and surveillance are impossible because traditional computer vision technologies are no more useful for massive processing and intelligent decision making. In this paper, a framework is proposed which enables both on spot data processing and intelligent decision making by using cloud computing. The developed application is a trained on Artificial Neural Network, which can handle different traffic techniques with congested traffic scenario and priorities traffic such as ambulance handling. The Message Queue Telemetry Transport protocol is used for green transmission with mobile access to traffic data. The results analyzed with thirty videos processed data which handle real-time data prioritization for the people for smart surveillance to fastest route and enhance the intelligent data transmission.

Combining unmanned aerial vehicles with artificial-intelligence technology for trafficcongestion recognition: Electronic eyes in the skies to spot clogged roads:

Unmanned aerial vehicles (UAVs) are gradually becoming useful and common. In the consumer electronics (CE) category, unmanned systems have changed the way monitoring by air is conducted in such fields as transportation, the environment, and emergency rescue. This article examines how UAVs combined with artificial-intelligence (AI) technology are used for recognizing traffic congestion. Congested roadways cause traffic delays, which wastes fuel, adds to pollution, and invites road rage. Society can benefit from technologies that help recognize and relieve traffic congestion. We present a practical framework for using UAVs to recognize traffic problems. According to this framework, images of traffic scenes are first captured by a UAV system based on route-planning technology. Then the aerial images are further processed by using convolutional neural networks (CNNs). Finally, the output is transferred to a traffic management center.

Impact of transportation network companies on urban congestion: Evidence from large-scale trajectory data: We collect vehicle trajectory data from major transportation network companies (TNCs) in New York City (NYC) in 2017 and 2019, and we use the trajectory data to understand how the growth of TNCs has impacted traffic congestion and emission in urban areas. By mining the large-scale trajectory data and conduct the case study in NYC, we confirm that the rise of TNC is the major contributing factor that makes urban traffic congestion worse. From 2017 to 2019, the number of for-hire vehicles (FHV) has increased by over 48% and served 90% more daily trips. These resulted in an average citywide speed reduction of 22.5% on weekdays, and the average speed in Manhattan decreased from 11.76 km/h in April 2017 to 9.56 km/h in March 2019. The heavier traffic congestion may have led to 136% more NOx, 152% more CO and 157% more HC emission per kilometer traveled by the FHV sector. Our results show that the traffic condition is consistently worse across different times of the day and at different locations in NYC. And we build the connection between the number of available FHVs and the reduction in travel speed between the two years of data and explain how the rise of TNC may impact traffic congestion in terms of moving speed and congestion time. The findings in our study provide valuable insights for different stakeholders and decision-makers in framing regulation and operation policies towards more effective and sustainable urban mobility.

3. METHODOOGY

The technologies developed in this context generally form the infrastructure of ADAS and autonomous driving systems. ADAS are systems that help drivers and vehicles detect dangerous traffic situations and respond to them accurately and quickly. These systems aim to increase driving safety and reduce the number of traffic accidents. Modern cars usually have ADAS systems integrated into their electronics, but other vehicles do not have such an integrated system. Traditional research methodologies of TSD mostly rely on manual feature extraction of various attributes such as geometrical shapes, edge detection, and color information. Color-based approach mostly comprises of threshold-based segmentation of traffic sign region in a particular color space such as Hue-Saturation Intensity (HSI), Hue-Chroma-Luminance (HCL) and others.

Drawbacks:

- **Limited Availability:** While modern cars are often equipped with integrated ADAS systems, the same cannot be said for other vehicles on the road. This lack of integration in non-modern vehicles creates a disparity in driving safety features, as they may not benefit from the advancements and protection provided by ADAS systems. This discrepancy increases the risk of accidents and compromises overall road safety.

- **Manual Feature Extraction:** Traditional research methodologies in Traffic Sign Detection (TSD) heavily rely on manual feature extraction. This process involves manually identifying and extracting various attributes, such as geometrical shapes, edge detection, and color information, from traffic signs. This approach is time-consuming, labor-intensive, and prone to human error, limiting the efficiency and accuracy of the system.

- **Sensitivity to Illumination Changes:** The existing system faces challenges when encountering changes in illumination that frequently occur in real-world scenarios. Variations in lighting conditions, such as glare from sunlight, shadows, or artificial lighting, can affect the perception and recognition of traffic signs. This sensitivity to illumination changes can lead to false positives or missed detections, compromising the reliability of the system.

- **Insufficient Driving Safety:** While ADAS systems aim to enhance driving safety and reduce the number of traffic accidents, the existing system may fall short in providing comprehensive safety measures. The reliance on manual feature extraction and limitations in handling illumination changes may result in inadequate detection and response to dangerous traffic situations. This can impact the overall driving safety and increase the risk of accidents and potential injuries.

This project introduces a portable and image-based Advanced Driver Assistance System (ADAS) that enables real-time detection of traffic signs, vehicles, and pedestrians. The system utilizes the YOLO v5 algorithm to achieve fast and accurate detection, making it a popular choice due to its high detection speed and accuracy.

The study offers several notable advantages. Firstly, the utilization of camera-based detection processes and computer vision techniques reduces the overall cost of implementing the system. By leveraging existing camera hardware and advanced computer vision algorithms, the need for additional expensive sensors or specialized equipment is minimized.

Another advantage of the developed system is its compatibility with embedded platforms, which contributes to improved efficiency and mobility. By optimizing the real-time system to run effectively on embedded devices, the researchers have enhanced the system's portability and practicality. This allows for its deployment in various scenarios, including in-car systems or other mobile devices, without relying on high-performance computing resources.

Furthermore, the study incorporates a recent comparison of the state-of-the-art detection algorithm, YOLO v5, on trendy embedded platforms. This evaluation ensures that the research remains up to date with the latest advancements and provides valuable insights into the performance and compatibility of the algorithm with different hardware setups. As a result, the study serves as a guide for researchers and practitioners interested in developing ADAS systems, offering them relevant information on the capabilities and effectiveness of the YOLO v5 algorithm.

In addition to YOLO v5, the paper briefly mentions other object detection frameworks such as YOLOv6 and Faster R-CNN. YOLOv6 is specifically designed for industrial applications, emphasizing hardware-friendly efficiency and high performance. On the other hand, Faster R-CNN is a single-stage model that streamlines the detection process by incorporating a region proposal network (RPN), which saves time compared to traditional algorithms like Selective

Search.
Furthermore, the paper mentions the use of the CNN-LSTM algorithm, which combines Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM). This approach involves employing a shallow CNN to extract primary features from the molten pool image, facilitating the detection process.
In summary, the paper introduces a portable and image-based ADAS system that utilizes the YOLO v5 algorithm for real-time detection. The study highlights advantages such as cost reduction through camera-based detection processes, compatibility with embedded platforms for improved efficiency and mobility, and up-to-date comparison of the algorithm's performance on trendy embedded platforms. Additionally, it briefly mentions other detection frameworks like YOLOv6 and Faster R-CNN, as well as the CNN-LSTM algorithm for feature extraction in specific applications.

Benefits:

➢ **Cost Reduction:** The utilization of camera-based detection processes and computer vision techniques helps reduce the overall cost of implementing the system. By leveraging existing camera hardware and advanced algorithms, the need for additional expensive sensors or specialized equipment is minimized.

➢ **Efficiency and Mobility:** The system's compatibility with embedded platforms enhances its efficiency and mobility. Optimizing the real-time system to run effectively on embedded devices allows for its deployment in various scenarios, such as in-car systems or other mobile devices. This eliminates the reliance on high-performance computing resources and ensures portability and practicality.

➢ **Up-to-Date Comparison:** The study includes a recent comparison of the state-of-the-art detection algorithm, YOLO v5, on trendy embedded platforms. By evaluating the algorithm's performance and compatibility with different hardware setups, the research remains up to date with the latest advancements. This information serves as a valuable guide for researchers and practitioners interested in developing ADAS systems.

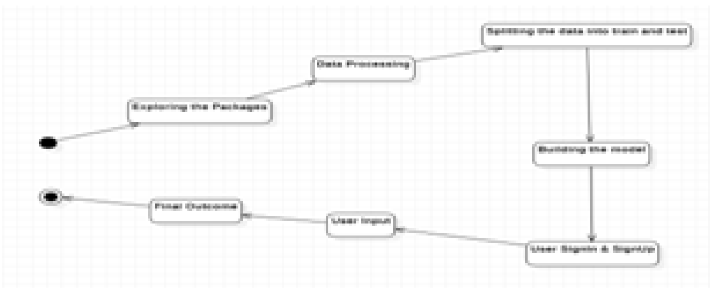

Fig 2 State Chart Diagram

Modules:

- Data exploration: using this module we will load data into system
- Processing: Using the module we will read data for processing
- Splitting data into train & test: using this module data will be divided into train & test
- Model generation: Model building - Yolov5, Yolov6, Faster-Rcnn and LSTM + CNN
- User signup & login: Using this module will get registration and login
- User input: Using this module will give input for prediction
- Prediction: final predicted displayed

4. IMPLEMENTATION

Algorithms:

➢ **Yolov5:** YOLOv5 is a modern object detection algorithm, that has been written in a PyTorch, Besides this, it's having, fast speed, high accuracy, easy to install and use. The importance of YOLOv5 was raised, due to its different export and deployment modules. It is perhaps the best-suited model for many datasets and training as it provides a good balance between speed and accuracy. YOLOv5l: It is the large model of the YOLOv5 family with 46.5 million parameters. It is ideal for datasets where we need to detect smaller objects.

➢ **Yolov6:** YOLOv6 is a single-stage object detection framework dedicated to industrial applications, with hardware-friendly efficient design and high performance.

➢ **Faster-Rcnn:** Faster R-CNN is a single-stage model that is trained end-to-end. It uses a novel region proposal network (RPN) for generating region proposals, which save time compared to traditional algorithms like Selective Search. It uses the ROI Pooling layer to extract a fixed-length feature vector from each region proposal.

➢ **LSTM + CNN:** The CNN–LSTM algorithm establishes a shallow CNN to extract the primary features of the molten pool image. Then the feature tensor extracted by the CNN is transformed into the feature matrix. Finally, the rows of the feature matrix are fed into the LSTM network for feature fusion.

EXPERIMENTAL RESULTS

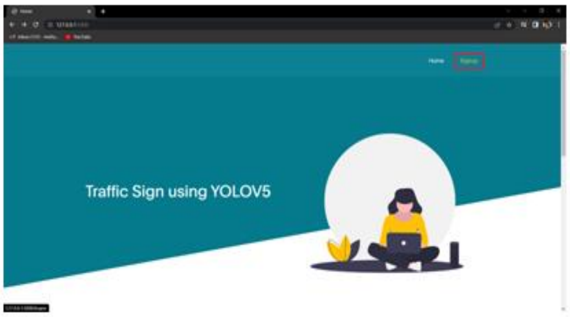

Fig 3 Home Page

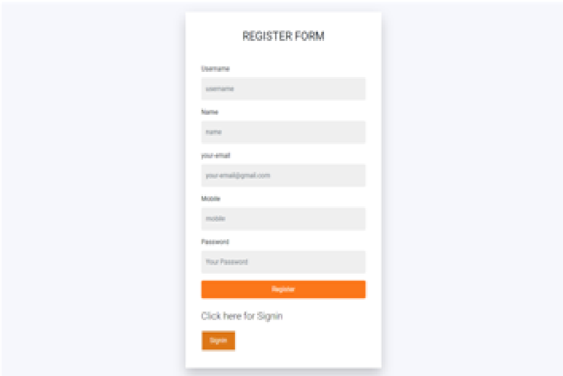

Fig 4 Registration Page

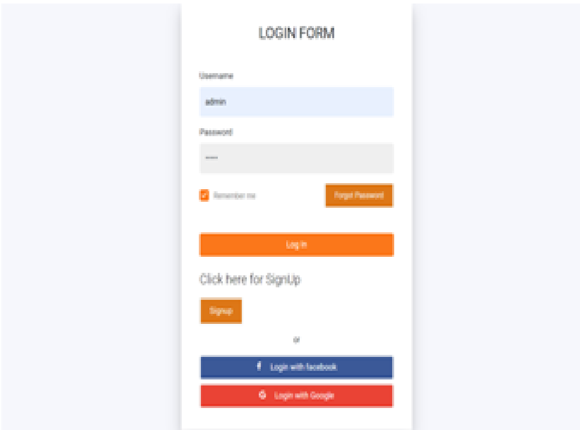

Fig 5 Sign in Page

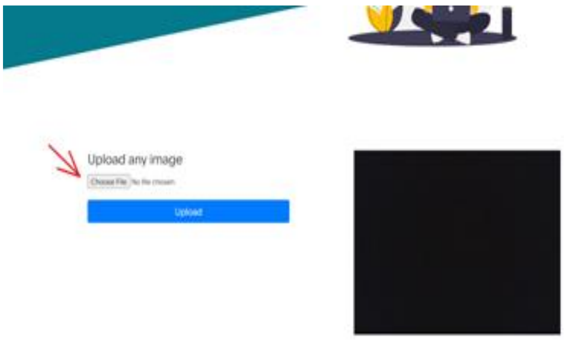

Fig 6 Main Page

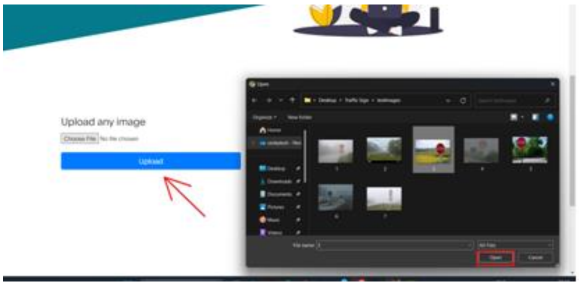

Fig 7 Upload Image

Fig 8 Prediction Result

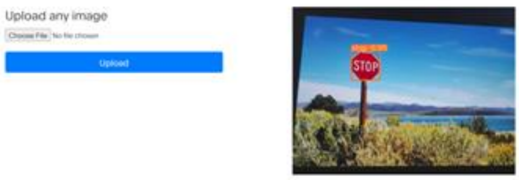

Fig 7 Prediction result from video

5. CONCLUSION

This project proposes a deep learning-based detection system for autonomous driving and driver assistance systems to contribute to mobility and portability. The proposed system implements applications on three different mobile GPU platforms that stand out in price and performance. For this purpose, the trend embedded platforms have implemented a real-time application that can detect vehicles, pedestrians, and traffic signs with the state-of-the-art YOLO v5 model. The experimental results show that the with low power consumption and high computational power provides high efficiency with the fastest inference speed and accuracy in detection.

6. FUTURE WORK

Future studies plan to expand the dataset with various illumination and environmental conditions such as motion blur, color fade, undesirable light, occlusion, rain and snow. In addition, the proposed model will be developed with the latest technology deep learning models. It will contribute to the ADAS system to better detect road objects. Besides, it is aimed to investigate novel methods to increase detection speed and accuracy in real-time. there is redundant research work emerging for recognizing traffic signs for handling with the real-world problems. On the one hand, in future, we will complete our benchmark by covering more types of the traffic signs in NZ so that we can make this project more instructional in this field. On the other hand, more object recognition techniques will be employed into TSR. For example, recognizing objects utilizes heatmaps methods. Finally, more evaluation measures also should be used to estimate the performance of different models

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