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Intelligent Vehicle Speed Limiting and Pothole Detection System: A Review

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Abstract

Speed is considered as the major cause of deaths on roads transport. As the speed goes higher, the more the chances of fatalities. Thus, there is a serious concern on speed management. Existing approaches to detect over speeding are not scalable and require manual efforts. It has been observed that potholes are detected but bumps are ignored, bumps are mounted on roads with special purposes and there is need for them to be recognized. It is undeniable that, these limitations need to be solved, hence this literature is aimed at identifying these limitations as research gaps and propose solutions for them. Hence, there is need to develop novel approach towards building a system which reduces the number of accidents due to driver's negligence of over speeding. Thus, the use of computer vision and artificial intelligence can address the aforementioned problem. This motivates us to vent into this context. This is a review on recent literature on vehicle speed limiting and pothole detection system. It is also organized to facilitate and support the work of researchers of like-minds, who put efforts towards computerizing the outmoded system for controlling speed to a robust design of intellectual speed controlling system based on AI for protection on motorways. The article intensely discovers algorithms for speed limit and pothole recognition powered by Artificial Intelligence (AI). The emphasis in this article therefore, are on the three primary metrics of performances for the speed recognition algorithms, vis-à-vis: accuracy, precision and robustness. This article finally identified the gaps in the existing literatures and then discusses a typical workable structural design.

Keywords: intelligent, vehicle, speed limit, pothole, accident.

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INTRODUCTION

In many countries, speeding has the highest percentage of traffic violations. This traffic violation puts everyone in the road on danger. According to NHTSA, 9717 people were killed due to speeding in 2017 in the USA (Patira, 2019). The aftermaths of speeding include increased stopping distance, increased fuel consumption, loss of vehicle control, economic losses, and to some extent, loss of lives. Additionally, the seat and seatbelts may malfunction to protect the passengers from the collision and crash as speeds get very high. Many countries including the US lose billions of dollars to their country's economy(Patira, 2019). As a result, the drive to build more efficient transport services using innovative organizational and technical solutions has prompted the development and implementation of intelligent transport systems (ITS) and smart(intelligent) vehicles. (Shadrin et al., 2017). Automation of road vehicles has been pulled by almost a century of research in several countries. Different scientific investigations (Naranjo, J.E., et al, 2016) have been conducted to address problems of automatic vehicle control, including the object component base, mathematical apparatus and its implementation, and technical vision systems. Only a small number of Advanced Driver Assistance Systems (ADASs), such as those found in cars that are produced in large quantities, have made it to the market. Recently, the development of automatic driving assistance systems (ADAS) has attracted more attention due to advances in artificial intelligence and system integration technologies. In ADAS, the design of a road-speed-limit warning function is a critical task to realise an automatic traffic sign recognition (TSR) module, which is an important subsystem to remind drivers of the detected traffic sign on the road. As earlier stated, speeding and lack of good road conditions (pothole) are the two major causes of fatal accidents (Santos et al., 2020).

In speed limit and decelerating control systems, direct collisions and emergency cases are being monitored using Forward Collision warning (FCW) and autonomous emergency braking (AEB) techniques, AEB can reduce the speed of a vehicle detected at a speed of 80-180 kilometre per hour and eventually stops the vehicle in the remaining cases (Araujo et al., 2012). In anti-lock decelerating system, wheel lockup may cause skidding and vehicle instability. This would limit the ability to modify the vehicle's direction. This issue can be controlled by using the ABS system, which allows the driver to stop forcefully and bring the system under control. ABS however has its own limitations. First of all, it cannot work under rainy as well as snowfall condition. Second, it could be a nightmare if the driver has not used the ABS at the appropriate moment, finally, the car with ABS is pricey (Jeppsson et al., 2018). Honda CMBS is great at detecting vehicles of both light and heavy weight, whether in the centre or side of the lane, and so on. The main limitation of this technology is that the sensor cannot detect if the vehicle is moving at less than 15km/hr; likewise, a light car parked along the side of the road cannot be detected. The system cannot function when the distance between both vehicles is tiny(Sam et al., 2016). Nissan's smart deceleration system automatically reduces the chance of collision by using laser radar sensors.

Based on a report given by FORD, a direct collision of a vehicle with obstacle is done through camera technology. An alert message together with a warning message are sent when a colliding object is sensed. Nissan's Intelligent emergency warns the driver visual and audio alerts in cases of applying brake. Other vehicles and obstacles movements are detected by a camera attached at the top portion of the windshield (Robert, 2009) the Nissan AEB employs radar technology to detect the vehicle's proximity to any object on the road and instruct the driver to take the necessary action (Eilbrecht et al., 2017). When a collision occurs, pre-collision assist along with AEB can immediately apply the brakes because pre-collision assists employs camera technology to monitor the entire vehicle's movement on the road. Pérez, J., et al (2010) provides a case study on an automated speed control system. The experiment is carried out using Arduino. ABS is designed to stop the car and avoid any unpleasant occurrences proactively.(Zhou et al., 2018). (Duan et al., 2017) has proposed emergency decelerating system based on traffic accident data statistics.

A fuzzy-logic controller was employed to provide artificial intelligence in the decelerating system that (Madhava et al., 2016) has developed for trains. Every sensor is managed by the micro controller. Ultrasonic transmitter-receiver controls the distance between a vehicle and the next vehicle. (Eilbrecht et al., 2017)has suggested a framework for model prediction. (Pérez et al., 2010) describes RFID based Intelligent Vehicle Speed controller. (Gunawan et al., 2021) employ Arduino Uno Microcontroller for the implementation of Automatic Decelerating system. To assess the distance between the vehicle and the obstacle, a sensor was located at the car's front end, the sensor also detects ultrasonic waves if any is found. The reflected wave from the ultrasonic receiver governs the decelerating circuit, causing the car to halt and lowering the likelihood of an accident. Additionally, (Anand et al., 2020) proposed an intelligent vehicle speed controlling system, using raspberry pi, the vehicle maximum speed is set automatically by using the speed limit sign board detected by SVM and speed limiter, unfortunately, the work was not carried out according to the content of the paper. Thus, the need for more automation for the speed limit and control system arises and have drag numerous remarkable so far. AI as a field of computer science and engineering can be used for different smart applications aiming to make intelligent control systems.

The success of vehicle speed controlling system is highly dependent on the accuracy of road traffic sign detection and classification. In this case, the improvement we propose on the previous works on road traffic detection and classification would ease our way for speed controlling system. Most researcher use microcontroller-based platform of the Arduino Uno board to develop the speed controlling system. In the work of (Sathiskumar et al., 2020), automated speed controlling system was built using the microcontroller-based platform of the Arduino Uno board. The Arduino Uno board is programmed in such a way that, the prescribed speed limit was incorporated in the transmitter unit which transmits the signals, and it was received by the receiver in the vehicle using Zigbee wireless signals.

Traffic signs are visual objects designed to be seen by drivers for the purpose of guiding the drivers and autonomous vehicles on proper utilization of the road. However, drivers find it difficult to recognize the signs due to some reasons of human nature such as tension, lack of knowledge about the signs or tiredness. the inability of drivers to recognize traffic signs puts passenger life in danger by causing fatal accidents on the road. In an effort to reduce over speeding while driving, globally, a Driver Support System (DSS) was proposed (Adell, 2009), DSS provides traffic signs at roadsides telling drivers the maximum speed limit allowed in a particular zone. Various countries follow similar set of traffic signs; these traffic signs are designed by well-defined laws. However, some drivers may not notice these traffic signs while driving due to some factors that can affect individual sight such as tiredness, weather condition and tension just to mention but few. To solve this problem, drivers need additional aid to support them in sighting the traffic signs automatically.

More so, an automated speed monitoring can be a paramount important to reduce over-speeding, this is achievable by improving the DSS performance using various methods and techniques. Initially, speed-limit sign (SLS) recognition is implemented using a global positioning system and a pre-established traffic sign database to notify drivers of any speed limitations that may emerge in front of their present location. However, this method may yield an incorrect alert result when the database does not update to the most recent version (Tsai et al., 2017). We suggest that, an expert system with a knowledge database comprising codified traffic laws would initially be adequate for operating a road vehicle in fully autonomous mode. In 1970, efforts were made to codify traffic laws in machine code. The primary issue is that traffic laws included in legal documents are sometimes vague and abstract because they are mostly written in human language. (Shadrin et al., 2017). Therefore, this problem highlights the requirement of an efficient and effective SLS recognition system to accurately identify the maximum speed-limit of the road in real-time (Tsai et al., 2017).

To improve DSS performance in aiding the drivers to automatically see and recognize the traffic signs, an Intelligent Transport System (ITS) was proposed using machine learning techniques. For the fifth level of SAE automation to be achieved, it is evident that road vehicles must be furnished with hybrid artificial intelligence systems that can solve driving tasks under unknown conditions. According to (Rizaldi & Althoff, 2015), there have been three main waves in the development of artificial intelligence (AI): (1) Wave of "handcrafted knowledge": this was the stage in the development of expert systems in which engineers created the sets of rules that represented the available knowledge in well-defined domains. Three major waves have emerged in the evolution of artificial intelligence (AI), according to Rizaldi, A. and M. Althoff (2015):

(1) Wave of "handcrafted knowledge": during this phase of expert system development, engineers developed sets of rules that reflected the body of knowledge in certain fields. The systems that were constructed had high reasoning but weak perception, little learning, and no abstracting abilities,

(2) Wave of "statistical learning": during this period, engineers developed statistical models for certain problem domains and trained them using huge data. This led to the development of neural networks like CNN and deep learning algorithms. The creations demonstrated poor reasoning and abstracting skills but good perception and learning. The current period of AI hybrid systems, which incorporate the benefits of the two innovations mentioned above, is known as the "contextual adaptation" wave. The present inventions appear to have a promising future in all counts (Shadrin et al., 2017).

One of the key elements for the implementation of improved advanced driver assistance systems (ADAS) with fully controlled and intelligent speed limiter systems is the recognition of speed limit signs (SLS). The primary benefit of the SLS is that drivers can no longer worry about their speed or fear of exceeding the posted speed limit, especially when driving. The system frees the driver from worrying about his speedometer so he may focus on the road. To achieve this, the system first employs a detection method based on artificial intelligence detection algorithms, and then recognises speed limit signs using an image classifier. Furthermore, this limit is fed into the speed limiter via MCU. The speed limiter then sets the maximum speed of the vehicle, restricting it from speeding (Anand et al., 2020). Thus, this paper presents a review of intelligent vehicle speed limiting and pothole detection system. This review can enable the research community to have an insight of next generation vehicles.

Speed is the leading cause of death on the roadways. The faster the speed, the greater the impact and the likelihood of serious damage or death. This is why speed management should be taken seriously. Existing methods for detecting excessive speeding are not scalable and involve manual effort. As a result, there is a need to explore unique approaches to establishing a system that decreases the amount of accidents caused by driver irresponsibility, such as speeding. Thus, the use of computer vision and artificial intelligence can address the aforementioned problem. This motivates us to vent into this context.

Speed Limit Sign Detection Systems

AI is a branch of computer science and engineering that develops smart applications with the goal of creating intelligent machines. AI works and responds in the same way as people do, intelligently and independently, by learning from experience and adapting to new interactions. AI has been used in a variety of practical domains. In March 2016, AlphaGo, developed by Google DeepMind, defeated Li Shishi. Not only did the DeepMind team make significant advances in AlphaGo, but also in speech synthesis, lip reading, and differentiable neural computers. In 2016, various firms and institutes became interested in unmanned vehicle research and development. The world's first unmanned taxi, NuTonomy, was driven on the road in August 2016 and was the first business to make unmanned vehicles available to the general public. Combining deep learning and reinforcement learning is the fundamental technology of artificial intelligence. Computational models with many processing layers can learn representations of data with different levels of abstraction thanks to deep learning.

Deep Neural Networks

Deep learning has advanced artificial intelligence in a number of domains, including speech recognition, visual object detection, and more, thanks to advancements in pre-training technologies and computer power. Convolutional neural networks (CNNs), recurrent neural networks (RNNs), deep belief networks (DBNs), and stacked autoencoders (SAE) are now the most used deep learning models. CNNs are increasingly being used to automatically learn features (Simonyan & Zisserman, 2014). A cascade AdaBoost classifier was trained using the features that were extracted using VGG in (Pang et al., 2016). CNNs strong ability to extract general and representative features without human intervention was demonstrated by their excellent performance.

However, these methods have always relied on a rectangle window of a fixed size, so they had to first get proposals from other methods like ACF(Dollár et al., 2014), stixel, edge boxes(Dollár & Zitnick, 2014). Mediated perception approaches use multiple initial subcomponents to recognise driving relevant objects like cars, pedestrians, lanes, traffic signs, and lights. The recognition findings are then merged into a consistent world representation of the car's immediate surroundings. Behavior reflex techniques build a direct mapping from a picture to a driving action. This concept dates back to the late 1980s, when Pomerleau, (1989) developed a neural network to create a direct mapping from an image to steering angles. (Chen et al., 2015) developed a direct perception technique for autonomous driving; they propose mapping an input image to a minimal number of important perception indicators that are directly tied to the affordance of a road/traffic state for driving (Chen et al., 2015). Their representation provides a collection of concise yet full descriptions of the scene, allowing a simple controller to drive independently. And they train a deep CNN with 12 hours of human driving to demonstrate that their model can successfully drive a car in a wide range of virtual situations.

Reinforcement Learning

Reinforcement learning (RL) tackles the scenario of a decision maker dealing with a sequential decision problem who uses evaluative feedback to assess performance (Mnih et al., 2016). The overall goal of RL is to create a 'good' mapping that links 'perceptions' to 'actions' and traditionally handles circumstances in which a single decision maker interacts with a stationary environment. The powerful methods and remarkable findings of RL (Mnih et al., 2015) have made this framework extremely prevalent among the computer science and robotic communities, and recently, there has been an increase in interest in extending RL methods to multi-agent situations. Markov games (also known as stochastic games) and their modifications or specialisations have been used to describe multi-agent RL difficulties (Mnih et al., 2013). A number of scholars implemented single-agent RL algorithms (with appropriate adjustments) in this multi-agent framework. Reinforcement learning algorithms and theories have become increasingly popular in practical engineering optimisation and control as research into them has advanced. Reinforcement learning has been successfully applied in nonlinear control, robot control, artificial intelligence, problem solving, combinatorial optimisation and scheduling, communication and digital signal processing, multi-agent, pattern recognition, and traffic control, among other fields. In recent years, particularly in the automatic driving technology of intelligent vehicles, RL learning has shown great promise. For instance, in 2016, the AlphaGo computers combined Reinforcement Learning algorithm and depth learning to propel the computer to a level higher than that of the top professional players, causing a global sensation. As a result, reinforcement learning, as a universal learning algorithm capable of solving the intelligent vehicle problem from perception to decision control, will gain momentum in a variety of real-world applications.

Taxonomy of Speed Limit Signs Recognition Algorithms

The recognition of speed limit signs (SLS) is one of the important components for the realization of improved advanced driver assistance system (ADAS) with fully control and intelligent speed limiter systems (Tsai et al., 2017) via first, the system uses a detection method based on artificial intelligence detection algorithms and recognizes speed-limit signs with image classifier(Saadna et al., 2019). Further this limit is provided input to the speed limiter through MCU. The speed limiter then sets the maximum speed of the vehicle which restricts the vehicle to over speed. This section reviews the AI techniques applied for SLS. The taxonomy categories the techniques into machine learning, deep learning and hybrid approaches.

Machine Learning for Control Speed Limit Signs Recognition

The following paragraphs discuss about various machine learning methods used for traffic signs detection and recognition which are the prerequisites for intelligent speed limiting system. The goal of ADAS is to assist drivers, and consequently to significantly decrease the number of accidents. These systems use technologies such as: global positioning, radar, image sensors and techniques of computer vision. Many of the ADAS systems use computer vision techniques in their operations for example. (Souani et al., 2014) proposed an efficient ANN algorithm for automatic road sign recognition and its hardware implementation. The study detects the road speed signs implemented in a Virtex4 FPGA family which is connected to a camera mounted in the moving vehicle. The system can be integrated into the dashboard of the vehicle. However, the research fails to embed the developed recognition system into the car speed limiter system.

Similarly, Tsai et al. (2017) proposed Real-time embedded implementation of robust speed-limit sign recognition using a novel centroid-to-contour description method base on SVM. This study addresses the design and implementation of a vision-based ADAS based on an image-based speed-limit sign (SLS) recognition algorithm, which can automatically detect and recognize SLS on the road in real-time. However, the study has not been implemented on embedded speed limiter systems.

Furthermore, Miyata, (2017b) suggested recognizing limits on speed-limit signs using ML, local binary pattern recognition, image processing with HSV, and a neural network. This paper demonstrates how to use a camera to recognize speed limit signs automatically. However, the study fails to integrate the created identification system with the car's speed restriction system.

Recently, Saadna et al. (2019) suggested a system for detecting and recognising speed restriction signs using SVM and MNIST datasets. The paper proposes a new picture segmentation method and uses the CHT transformation (circular hog transform) to determine the speed restriction. However, more work is needed to refine the detection phase, add a tracking module for testing video datasets, and deploy the system on a smartphone.

More recently in 2020, Anand et al. (2020) developed an intelligent Speed Controlling and Pothole Detection System via HOG and SVM. The system uses a signboard placed on the roadside to determine the safe driving speed of a vehicle in that area and sets the vehicle's maximum speed. Similar to previous studies, the research does not integrate the developed recognition system into the car speed limiter system. Researchers in (Lillo-Castellano et al., 2015) demonstrated an automated technique to independently identify chromatic and achromatic traffic signs in photos captured in realistic settings using two machine learning algorithms, K-Nearest Neighbour (K-NN) and Support Vector Machine (SVM), which were thought to be the most effective machine learning algorithms used in traffic sign detection. Three steps are included in the research's detection and classification of traffic signs. Image segmentation by utilizing the L*a*b* and HSI spaces comes first, followed by a post-processing step that enhances the segmentation results and, lastly, an SVM algorithm that was used to categorize the segmented regions' shapes and recognize traffic signs. Unfortunately, this method's limitations include its inability to produce accurate results on huge datasets and SVM's poor classification strength on video pictures (Lee & Kim, 2018) which can lead to a high number of false positives.

An improved Support Vector Machine (SVM) algorithm that decreased the rate of false positives was used along with Histogram Orientated Gradient (HOG) to capture form and aspect properties in sign detection to address the issue with normal SVM (Bouti et al., 2020). However, the process is highly costly.

An SVM classifier achieved 94.6% accuracy in (Ellahyani et al., 2016), when used to classify traffic signs. An improvement over the single SVM classifier was shown when this result was compared to the Random Forest classifier in conjunction with HOG. Like a lot of related studies. Like many similar researches, (Ellahyani et al., 2016) work requires high computational cost. One major drawback of the aforementioned techniques of traffic sign detection and classification is the fact that, they are based on hand-crafted features extraction. This makes their model slower than expected. Another approach for improving the speed and accuracy of image detection was proposed by (Anand et al., 2020), the researchers proposed MSER for both detection and classification of traffic signs. However, the proposed method was not implemented. Having reviewed some related literature on traffic sign detection and classification. The summary of the achievements and limitation of each paper were summarized in Table 1.

Table 1. Summary of comparison of related work based on working principles and drawbacks

Reference	Working Principle	AI algorithms used	Drawbacks
, (Singh & Malik, 2022)	proposed a CNN based approach to develop a model that detects and recognizes road traffic signs with accuracy of 95%, 97.8% precision and recall of 98.06.	CNN	CNN is slow in real-time image classification due to its computational complexity
(Tsai et al., 2017)	This project focusses on designing and implementing a vision-based ADAS that recognises speed-limit signs (SLS) on the road in real-time.	SVM classifier	The system gets slow with larger datasets.
(Gomes et al., 2017)	This research incorporates an algorithm for automatically identifying speed limit signs and interpreting the sign's data, such as the speed limiter's maximum speed limit.	Algorithms used include KNN, SVM,optimum-path forest classifier (OPF), and least mean squares.	The methodology has a limitation of generating error by large rotations.
(Saadna et al., 2019)	a new segmentation method is proposed to segment the image, and the CHT transformation (circle hog transform) is used to detect the speed limit	SVM	The methodology has a slow detection phase.
(Anand et al., 2020)	The system sets the maximum speed of vehicle with the help of sign board available on the roads which define the safe driving speed of vehicle for that area.	HOG and SVM	Method not evaluated.
(Lillo-Castellano et al., 2015)	SVM is a powerful classification algorithms	HOG and Support Vector Machine	Slow performance in large dataset
(Ellahyani et al., 2016)	classification and obtained an accuracy of 94.6%.	an SVM classifier was used for traffic sign	High computation cost
(Kumar, 2018)	State-of-the-art accuracy of 97.6% on German Traffic Sign Recognition Benchmark (GTSRB).	Capsule Networks method was developed, the method has achieved the	It has an issue of high dimensionality in the data
(Lee & Kim, 2018)	The researchers used CNN and developed efficient traffic sign detection method where locations of traffic signs are estimated together with their precise boundaries	CNN	Trade-off between speed and accuracy is of great concern
(Anand et al., 2020)	Not stated	The researchers used MSER for both detection and classification of traffic signs	Method not evaluated

Deep Learning for Control Speed Limit Signs Recognition

Road traffic sign identification and recognition have greatly improved with the advent of Deep Learning, particularly the Convolutional Neural Network (CNN). This technique detects and categorizes traffic indicators using a learning-based methodology. The technique has solved the problem of manually extracting features that existed in conventional machine learning methods.

Recent advances in deep learning have had a substantial impact on cutting-edge results for speed limit recognition and object detection (Dewi et al., 2020). Much of the study focused on developing deep convolutional neural networks to enhance accuracy. Nonetheless, the creation of a consistent real-time speed limit sign identification remains a difficult topic because to the latency in testing time, which is critical in making decisions based on the environment and real-world variability. Several well-known researchers including (Lee & Kim, 2018) have utilised deep learning to detect and classify traffic signs, in their work, they employed CNN to create an effective traffic sign detection technique that estimates the locations of traffic signs along with their exact limits. Although the model's classification accuracy on traffic signs has been optimised, computations takes a long time complete.

Kumar, (2018) created a unique Model for Traffic Sign Detection Using Capsule Networks approach, which obtained state-of-the-art accuracy of 97.6% on the German Traffic Sign Recognition Benchmark. However, this approach has an issue of large dimensionality in the data, which means that the number of dimensions is enormous; hence, calculations rise in the time complexity.

Similarly in(Lee & Kim, 2018), a single CNN successfully solves a 2-D pose and shape class prediction problem that involves boundary estimation of traffic signs. The problem with this methodology is the trade-off between speed and precision.

Additionally, (Li et al., 2016) suggested a CNN-based speed limit sign detecting algorithm. With low-resolution training images and a small dataset size, the Cuda-convnet is selected as an appropriate model for the traffic sign recognition problem. The method increases the area under the precision-recall curve (AUC) of speed limit sign identification by more than 5% when compared to the state-of-the-art ACF detector, which has nearly flawless detection accuracy except for U.S. speed limit signs. However, the method is not added to a full system for detection and recognized speed limit automation.

Furthermore, proposed deep learning traffic sign detection, recognition and augmentation. The developed model base on deep CNN was set to detect several traffic signs including speed limit with excellent performance. However, the model suffers from high computational time. Moreso, (Farag & Saleh, 2018) suggested using deep learning to identify traffic signs for autonomous driving. Following considerable testing, a deep fifteen-layer CNN architecture was chosen for implementation. The suggested method successfully identified 100% of the robustness data set and 96.5% of the testing data set. However, the study fails to embed the developed recognition system into the car speed limiter system. Similarly, (William et al., 2019) suggested a Deep Learning-based F-RCNN Traffic Signs Detection and Recognition System. The German Traffic Signs Detection Benchmark (GTSDB) dataset was used to refine the previously described models. Even in challenging real-world driving scenarios, the F-RCNN Inception v2 model has produced accurate, dependable, and quick results by utilising a fully convolutional network and transfer learning (average of 96% accuracy).

Weight analysis was recently proposed by (Dewi et al., 2020) for the detection and recognition of different prohibitor signs using YOLO deep learning algorithms. A comparison study of Yolo V3 and Yolo V3 SPP is carried out using the darknet framework's various weights. concentrates on just one benchmark dataset. The Yolo V3 SPP outperforms all other models in terms of mean average precision (mAP), according to experimental results. The best average accuracy was achieved by Yolo D, who scored 99.0%, followed by Yolo E and F, who scored 98.9%. Yolo V3 SPP's detection time increases with its accuracy, but it takes longer to recognize the sign. The summary of related work is depicted in Table 2.

Table 2. Summary on comparison of researches conducted on speed limit sign recognition using deep learning methods

References	Working Principle	AI algorithms used	Drawbacks
Li et al. (2016)	Cuda-convnet is selected as an appropriate model for the traffic sign recognition problem. The method increases the AUC of speed limit sign identification by more than 5% when compared to the state-of-the-art ACF detector.	CNN	The method is not added to a full system which can detection and recognized speed limit
Abdi & Meddeb, (2017)	The created model was configured to recognize a number of traffic indicators, such as the speed limit.	Deep CNN	High processing time.
Farag & Saleh (2018)	The deployed CNN architecture is a deep fifteen-layer network, which was chosen after thorough experimentation.	CNN	Fail to embed the developed recognition system into the car speed limiter system
William et al. (2019)	The German Traffic Signs Detection Benchmark (GTSDB) dataset was used to refine the previously described models.	F-RCNN	Uses few training samples which degrades the accuracy
Dewi et al. (2020)	Yolo V3 and Yolo V3 SPP are compared in the study using various weights that the darknet framework provides.	YOLO	needs more time to identify the sign

Hybrid Algorithms for Control Speed Limit Signs Recognition

Even though a lot of research has been done on detecting and tracking speed limit signs, there is still a significant lack of relevant speed sign recognition systems to be embedded into intelligent speed limiter devices. This is because the need for road transportation and vehicles is growing daily, which is proportionate to the number of accidents that eventually occur. At this point, developing an intelligent vehicle system and other safety-driven driver assistance systems has become the norm (Balasundaram et al., 2012). Hybrid and ensemble approach have shown to compliment the deficiency in conventional deep learning algorithms. For instance, (Balasundaram et al., 2012) specifies the implementation of iReSign, a next-generation two-tier identity classifier based traffic sign recognition system architecture using Zernike and GFD algorithms for the future intelligent vehicle systems. Using a new hybrid approach that combines Zernike Moments and GFD, iReSign produced 92% cross validation accuracy and 95% testing recognition accuracy. However, the model suffers from computational complexity. The high computational requirement of hybrid and ensemble approaches has resulted to few and limited application of this technique in this context of research.

The proposed taxonomy in Figure 1 demonstrates the use of artificial intelligence algorithms to detect speed limit signs for autonomous vehicles. The taxonomy divides intelligent algorithms into four categories: traditional machine learning, deep learning, ensemble, and hybrid model approaches. The use of intelligent algorithms for detecting speed limit signs in autonomous vehicles has been investigated, as detailed in the preceding sections. Different types of intelligent algorithms were applied for this task, and it's shown remarkable performance. The work was carried out using a variety of sophisticated algorithms, which performed flawlessly. The intelligent algorithm's performance in the detection of speed limit signs for autonomous vehicles has outperformed previous methods. This indicates that intelligent algorithms have the potential to improve the accuracy of speed limit sign detecting systems when used in a real-world situation.

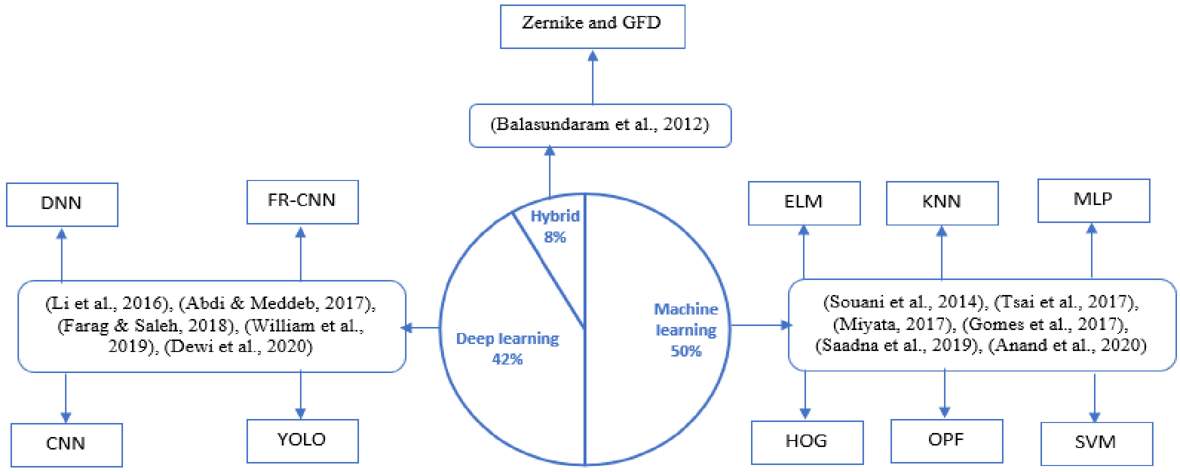

Figure 1 Taxonomy of intelligent algorithms applied for the detection of speed limit signs in autonomous system

Figure 1 depicts the proportion of intelligent algorithms applied to speed limit signs. The descriptive statistics show that the most commonly used methods by academics to detect speed limit signs are machine learning (SVM) and deep learning (CNN). As can be observed, deep learning systems based on CNN architecture are the most advanced for detecting speed limits (see Fig. 2).

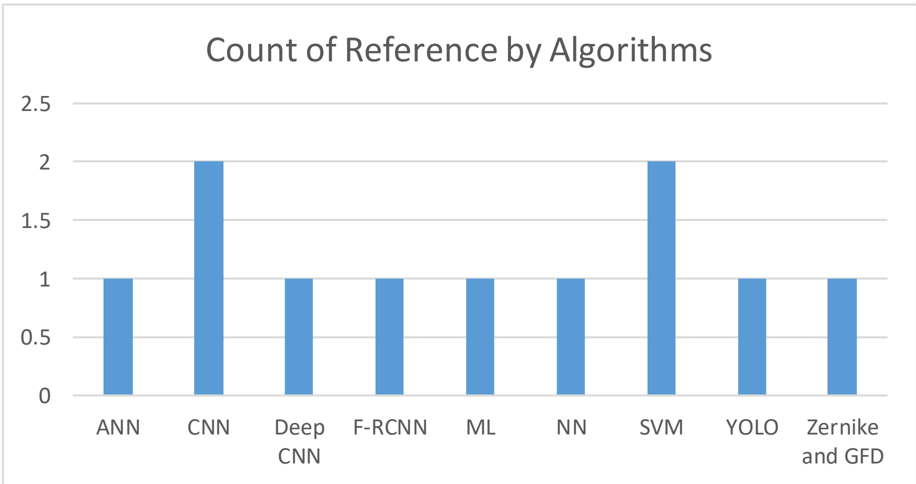

Figure 2 Count of research works by algorithms

Though, the thought of applying artificial intelligence learning algorithms for detecting speed limit is still in an infant stage considering the time that the literature on the application of AI in speed limiter system starts appearing (see Figure 1). More so, the ensemble and hybrid approach with only 8% of the publications have emerged with prominent results demonstrating it superiority over the individual approach, but the computational and implementation complexity still opens a niche that needs such model be build base on simple and effective algorithms. The overall performance evaluation of the AI speed limits signs recognition algorithms is presented in Table 3.

Pothole and Bumps Detection System

Pothole and Bumps detection systems is the recent approach in use to automatically detect road objects (Anaissi et al., 2019). Pothole and Bumps are the second most dangerous causes of accidents after over speeding (Anand et al., 2020). We studied some literature on road pothole and bumps detection. Table 2 contains the summary some recent literature in the application of various machine learning approaches to detect and classify road objects. The table also included some literature on speed detection and controlling systems all implemented with machine learning algorithms. Finally, limitations of each paper are stated which is an opportunity for further research. Table 3 depict the summary of Some Related Literature on Pothole and Bumps Detection System.

Table 3 Summary of comparison between some related literature on pothole and bumps detection System based on achievements, techniques used and limitations.

References	Achievements	Technique(s) Used	Drawbacks/Limitations
(Srivastava et al., 2018)	A road maintenance system utilizing basic ultrasonic sensors, Raspberry Pi, and a mobile phone was developed.	Internet of Things and Raspberry Pi and a Mobile phone	Cloud storage needed for storing GPS data, this means that a driver must have a smart phone to benefit this work
Ghadge et al. (2015)	The Bumps Detection System (BDS) uses an accelerometer to identify potholes and GPS to calculate their locations on Google Maps.	A smartphone-based approach that analyzes driving conditions using an accelerometer and GPS sensors.	System was trained to only detect bumps, other speed limit objects like potholes are not detected
Kamalesh et al. (2021)	developed a straightforward, portable, and reasonably priced IoT-based tool to identify potholes and notify the appropriate authorities of any damage.	The Raspberry Pi3 Single Board Computer (SBC) was used to successfully create the system, which allowed for image collection, analysis and email communication protocol.	The system is only implementable on customized motorbikes. Cannot be implemented on other vehicles.
Wu et al. (2020)	introduced a lightweight architecture to sense and analyze potholes based on data collected with smartphones.	The researchers improve some algorithms for real-time road-anomaly detection using smartphones using Z-Thresh, Z-Diff, STDEV and DVA	Two-way data processing needs a lot of energy consumption.
Mubarak et al. (2022)	The researchers designed a model which can detect and predict the potholes and different anomalies present in the road using different suitable algorithms of machine learning and deep learning.	Decision Tree, SVM and Linear Regression	System cannot report detected potholes for proper actions
Anand et al. (2020)	Proposed a Dynamic Speed Limiter with the help of machine learning algorithm which will help in reducing the accidents caused due to over speeding and rash driving of vehicles on road.	Raspberry was used to detect the potholes, accelerometer vibrations are set.	System not evaluated

Performance Evaluation of Speed Limit Signs and Pothole Detection Algorithms
This sub section presents the performance evaluation of the speed limit signs and pothole recognition algorithms that has been surveyed in the literature so far. The performance evaluation focuses on the data source and detection accuracy, precision, and recall respectively. Table 4. Shows he overall performance evaluation for comparison purpose.

Table 4. Performance comparison of speed limit recognition model by datasets, accuracy, precision and recall.

Reference	Algorithms	Datasets Source	Accuracy (%)	Precision (%)	Recall (%)
Balasundaram et al. (2012)	Zernike and GFD	Detection Camera	95	**X**	**X**
Souani et al. (2014)	ANN	Detection Camera	90	X	X
Li et al. (2016)	CNN	U.S. traffic signs	89.9	99.9	99.61
Tsai et al. (2017)	SVM	German traffic sign dataset	98	98	99
Miyata (2017b)	NN	Detection Camera	97.1	X	X
Gomes et al. (2017)	ML	Detection Camera	99.82	X	X
Abdi & Meddeb (2017)	Deep CNN	GTSRB dataset	99.58	99.13	99.21
Farag & Saleh (2018)	CNN	GTSRB dataset	96.5	X	X
Saadna et al. (2019)	SVM	GTSB, BTSD and STS datasets	X	50.16	94.96
William et al. (2019)	F-RCNN	(GTSDB)	96	X	X
Dewi et al. (2020)	YOLO	Taiwan traffic datasets	X	99	99

From Table 4, the most commonly used datasets for detecting speed limit signs and potholes are the detection camera and the German and Belgian traffic datasets, as shown in Figure 3. Based on the survey, most research uses the detection camera to capture the traffic signs and employs artificial intelligence detection algorithms to recognize the speed limit signs with image classifier. This limit is then provided as input to the speed limiter through the vehicle ECU. It was also discovered that CNN is the most effective model. Many tech companies, including Google, Microsoft, and Facebook, have active research groups exploring new CNN architectures, demonstrating that CNNs are one of the best learning algorithms for understanding and analysing image content, with high performance in image classification. CNNs are utilized for picture classification and recognition because they are highly accurate (Khan et al., 2020). Using a hierarchical architecture, CNN builds a network in the shape of a funnel before releasing a fully-connected layer where all of the neurons are coupled to one another and the output is processed.(Raundale & Maredia, 2021).

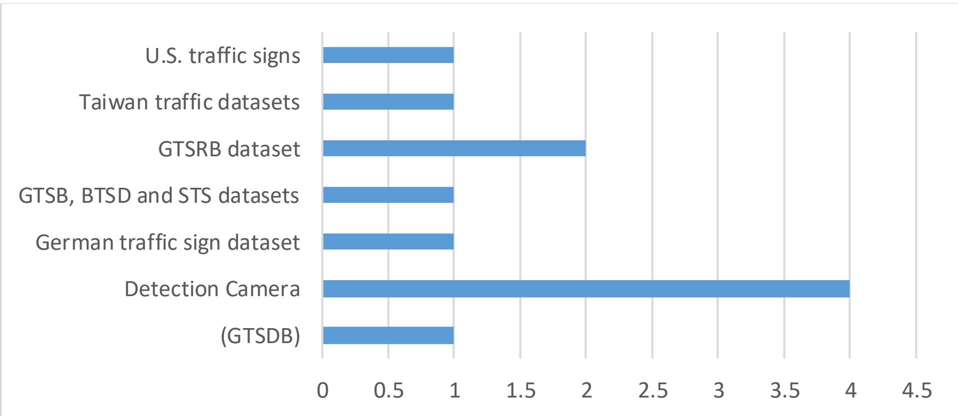

Figure 3 Count of research works by datasets

Directions for future research

In the review of related literature on the application of machine learning algorithms in detection and classifications of road traffic anomalies, it was discovered that, machine learning algorithms have performed well. However, the classical machine learning algorithms are based on handcrafted method for feature extraction, this makes the ML algorithms slower. To improve the performance of the ML algorithms, deep learning algorithms were employed and have yielded promising results. Accuracy of 97.6% was recorded as the highest percentage obtained in the literature. This percentage needs to be improved. Also in the literature, there is no action on faded speed limit sign`s. Also in the literatures, it was observed that potholes are detected but bumps are ignored, bumps are mounted on roads with special purposes and are need to be recognized. It is undeniable that, these limitations need to be solved, hence this literature is aimed at identify these limitations as research gaps and proposes solutions for them. Base on the survey, we have seen that a number of research have been proposed recently in the context of speed limits sign recognition to enable the realization of AV and its integration into intelligence speed limiter system. CNN is one of the widely used artificial intelligence algorithms. Base on the survey, we identified a number of open issues that needs to be address by researchers. The following drawbacks are identified from the reviewed literatures.

a) The existing system developed is able to detect and recognize the speed limit signs satisfactorily. The created method successfully segmented speed signals and accurately detected their values. However, more study is needed to incorporate these identification models into intelligent speed restriction devices for future autonomous vehicles. This is extremely handy when implemented in an embedded system. Since the lighting conditions and captured images are random, the processing algorithm must be resilient and efficient.(Souani et al., 2014).

b) b) In addition to these particular improvements, this technique ought to be incorporated into a comprehensive system that not only detects but also recognizes a variety of sign types, including but not restricted to speed limit signs. A whole detect-classify pipeline of this type would make up a comprehensive TSR system.(Li et al., 2016).

c) Despite positive findings, present research (Gomes et al., 2017) has limitations. First, the system employed has limitations in terms of the distance between the image device and the speed limit sign, as well as the rotation involved, because when these are excessive, the identification may be incorrect.

d)) Improving speed limit detection and recognition requires reducing processing time, which is now too long to inform drivers adequately. It is possible that using a convoluted neural network or similar methods will result in additional improvement t(Miyata, 2017b). It is anticipated that fixes to these concerns would be of greater utility in driver support when automated driving is implemented.

Conclusion

The emergence of communication technologies prompted car businesses around the world to spend heavily in Advanced Driver Assistance Systems (ADAS) to assure accident-free travel, pollution reduction, and fuel saving. ADAS fulfils its objectives by integrating sophisticated subsystems such as obstacle avoidance, overtaking advise, lane change aid, shortest route planning, parking help, and speed restriction devices with upcoming AI-based technologies. This article focuses on AI's potential for speed limiting in autonomous vehicles. This review delves thoroughly into speed limit recognition algorithms backed by artificial intelligence (AI). This article focuses on the three key performance parameters of speed recognition algorithms: accuracy, precision, and robustness. Finally, this paper addresses a typical functional architecture and the gaps found in previous research. This paper is designed to help researchers who are working on automating traditional speed limiting systems and developing intelligent speed restricting systems based on AI for road safety.

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