A REVIEW ON VEHICLE SPEED CONTROLLING AND POTHOLE DETECTION SYSTEM

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ABSTRACT

Road transport is considered as one of the major aspects of promoting Nigeria's economy. It is also considered as a basis of social and political interaction among the citizenry. There are many causes of road traffic accidents but the major ones are over speeding and potholes, bumps. In effort to reduce over speeding while driving globally, a Driver Support System (DSS) was proposed recently. To improve DSS performance in aiding the drivers to see and recognize the traffic signs, a Computer Image Vision Feature extraction was developed. Popular techniques used in these methods include Histogram Oriented Gradients (HOG) which was good for detection of pedestrians and Scale Invariant Feature Transform (SIFT) that was good in classification. However, this method has the limitation of being based on hand-crafted features extraction which makes it a semi-manual method. Accuracy is another issue associated with the mentioned method. A more accurate and faster approach is needed to quickly and accurately detects and classifies the traffic signs. With the emergence of machine learning algorithms, researchers make improvements in the detection and classification of road traffic signs. Hence, this paper conducts a survey on machine learning approach used for vehicle speed controlling and pothole detection. Hence, this review can aid researchers identified future opportunities that requires more attention.

Keyword: - *Machine Learning, Pothole Detection, Speed Control System, Road Sign Detection*

1. INTRODUCTION

Road transport is considered as one of the major aspects of promoting Nigeria's economy. It is also considered as a basis of social and political interaction among the citizenry (Sanusi et al., 2016). With all these tremendous contributions of road transport system in Nigeria, road traffic accident is an issue of major concern (Oluwaseyi & Gbadamosi, 2017). There are many causes of road traffic accidents but the major ones are over speeding (Sathiskumar et al., 2020) and potholes, bumps (Kamalesh et al., 2021). In Nigeria, there are corporations and agencies that oversee and control the occurrence of over speeding such as Federal Road Safety Corps and for maintaining the status of roads such as Federal Road Maintenance Agency (FERMA). However, these agencies mostly operate manually which is associated with time consumption, high cost and sometimes give inefficient results.

In 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 that zone. However, some drivers may not notice these traffic signs due to some factors that can affect individual sight such as tiredness, weather condition and tension. Drivers need additional aid to support them in sighting the traffic signs automatically. To improve DSS performance in aiding the drivers to see and recognize the traffic signs, a Computer Image Vision Feature extraction was developed. Popular techniques used in this methods include Histogram Oriented Gradients (HOG) which was good for detection of pedestrians and Scale Invariant Feature Transform (SIFT) (Dalal et al., 2006) that was good in classification. However, this method has the limitation of being based on hand-crafted features extraction which makes it a semi-manual method. Accuracy is another issue associated with

the mentioned method. A more accurate and faster approach is needed to quickly and accurately detects and classifies the traffic signs. With the emergence of machine learning algorithms, researchers make improvements in the detection and classification of road traffic signs. Recognizing traffic signs is mainly done in two stages including detection stage and classification stage. The detection module performs a multi-scale analysis on the image in order to locate the patches consisting only of one traffic sign. Next, the classification module analyses each patch individually and classifies them into classes of traffic signs (Aghdam et al., 2016). We are going to explain each stage based on the available literature.

2. LITERATURE REVIEW

2.1 Road sign Detection and Classification

Generally, there are three classes of road signs detection methods: these include colour-based, shape-based and machine learning-based methods. The dominant colours of most road signs are red, blue or yellow. These dominant colours are used to detect regions of interest (ROIs). Many authors (Lillo-Castellano et al., 2015) and (Ellahyani et al., 2016) use colour-based method to detect traffic signs. The problem associated with colour-based methods is that, the quality of image is affected by different lightening condition. This can affect the accuracy of detecting proper road traffic sign objects (Bouti, 2019). To overcome the problem of colour-based image detection method, researchers apply a shape-based method of road sign detection. In this method, the contours of the image are analysed by a structural or global approach. Shape-based methods are generally robust than colour-based methods by reason they can process images in grayscale and treat their gradients.

However, they are costly in computation time, given the fact that the rate of treatment depends largely on the number of detected edges (Saadna & Behloul, 2019). In addition to cost, this method is very sensible to occlusions and deformation that affects considerably their performances.The third and final method for traffic signs detection is the application of Machine learning. With the advent of machine learning algorithms, researcher employ various machine learning techniques to overcome the problems of road sign detection faced by colour-based and shape-based methods. Two machine learning algorithms, the *K*-Nearest Neighbour (K-NN) and Support Vector Machine (SVM) were considered to be the most powerful machine learning used in traffic sign detection (Lillo-Castellano et al., 2015), the researchers in this work presented an automated method to separately detect chromatic and achromatic traffic signs in images taken in realistic scenarios. The research detects and classifies traffic signs in three stages. First is image segmentation using the $L^*a^*b^*$ and HSI spaces, secondly a post-processing stage which improves the segmentation results and finally an SVM algorithm was used to classify the shape of the segmented regions and to identify traffic signs. The problem associated with this method is the fact that it cannot give proper result on large dataset, another problem is the classification power of SVM which is low on video images (Lee & Kim, 2018) and can result in false positives.

To overcome the problem associated with Support Vector Machine, (Bouti, 2019) employed an improved Support Vector Machine (SVM) algorithm that reduced the rate of false positive, together with the use of HOG to capture shape and aspect characteristics in detecting signs. The method is however, very expensive. In (Ellahyani et al., 2016), an SVM classifier was used for traffic sign classification and obtained an accuracy of 94.6%. This result was compared with Random Forest classier combined with HOG and found an improvement over the lone SVM classifier. Like many similar researches, (Ellahyani et al., 2016) requires high computational cost. One major limitation of the mentioned methods 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.

2.2 Learning-Based Approach for Traffic Sign Detection and Classification

With the emergence of Deep Learning especially the Convolutional Neural Network (CNN), a great improvement has been achieved in road traffic signs detection and classification. This method uses a learning-based approach to detect and classify traffic signs. The method has eliminated the issue of handcrafted feature extraction found in the traditional machine learning algorithms. There are different algorithms of deep learning. We can cite:

2.2.1 Deep Neural Networks

These networks are like MLP (multilayer perceptron) networks but with more hidden layers. The increase in the number of layers allows a network of neurons to detect slight variations of the learning model, favouring over-learning or over-fitting.

2.2.2 Convolutional Neural Networks (CNN)

The problem is divided into subparts, and for each part, a cluster of neurons will be created to study this specific portion. For example, for a colour image, it is possible to divide the image over width, height and depth (colours).

2.2.3 Deep Belief Network Machine

These algorithms work in a non-supervised first phase, followed by supervised classical training. This unsupervised learning step, furthermore, facilitates supervised learning. Popular researchers that apply deep learning in traffic signs detection and classification include (Lee & Kim, 2018), in their work, the researchers used CNN and developed efficient traffic sign detection method where locations of traffic signs are estimated together with their precise boundaries. The work has maximized the classification accuracy on traffic signs but the model is slow during computation processes.

In the work of (Kumar, 2018), a novel Model for Traffic Sign Detection Using Capsule Networks method was developed, the method has achieved the state-of-the-art accuracy of 97.6% on German Traffic Sign Recognition Benchmark (GTSRB). However, this approach has an issue of high dimensionality in the data, meaning that the number of dimensions is hugely high; therefore, calculations increase in the time complexity.

In (Lee & Kim, 2018), a boundary estimation of traffic sign is formulated as 2-D pose and shape class prediction problem, and this is effectively solved by a single CNN. The trade-off between accuracy and speed is the issue associated with this model. (Bangquan & Xiong, 2019) has improved both the speed and the accuracy rate of 98.6% using depthwise separable convolution (DSC) on German Traffic Sign Recognition Benchmark (GTSRB).

Another approach for improving the speed and accuracy of image detection was the work of (Anand et al., 2020), in this paper, the researchers used MSER for both detection and classification of traffic signs. However, the proposed method was not evaluated.

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 Machine Learning Approaches used in Detection and Classification of Road Objects

S/No	Reference	Paper Title	Technique(s) Used	Achievements	Drawbacks/Limitations
1.	Lillo-Castellano et al., 2015)	Traffic sign segmentation and classification using statistical learning methods	HOG and Support Vector Machine	SVM is a powerful classification algorithm	Slow performance in large dataset
2.	Ellahyani et al., 2016	Traffic sign detection and recognition based on random forests	an SVM classifier was used for traffic sign	classification and obtained an accuracy of 94.6%.	High computation cost
3.	Kumar, 2018	Novel Deep Learning Model for Traffic Sign Detection Using Capsule Networks	a novel Model for Traffic Sign Detection Using Capsule Networks method was developed, the method has achieved the	State-of-the-art accuracy of 97.6% on German Traffic Sign Recognition Benchmark (GTSRB).	has an issue of high dimensionality in the data
4.	Lee & Kim, 2018	Simultaneous Traffic Sign Detection and Boundary Estimation Using Convolutional Neural Network	CNN	The researchers used CNN and developed efficient traffic sign detection method where	Trade-off between speed and accuracy is of great concern

				locations of traffic signs are estimated together with their precise boundaries	
5.	Bangquan & Xiong, 2019	Real-Time Embedded Traffic Sign Recognition Using Efficient Convolutional Neural Network	Depthwise Separable Convolution (DSC) on German Traffic Sign Recognition Benchmark (GTSRB)	Has improved both the speed and the accuracy rate of 98.6%	The model is not cost-effective
6.	Anand et al., 2020	Intelligent Vehicle Speed Controlling and Pothole Detection System	The researchers used MSER for both detection and classification of traffic signs	Not stated	Method not evaluated

From the literature, it has been clearly seen that machine learning algorithms show promising results in detecting, classifying road traffic signs. Despite the achievements, a lot is needed to be done to improve the performance of the said algorithms. The limitations discovered in the literature include, slowness, accuracy and cases of false positives. In the case of slowness (speed), a hybridized model can improve the speed, likewise the accuracy. For the false positive, an improved Deep Neural Network can reduce the false positive.

2.3 Speed Control System

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.(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 ML and speed limiter, unfortunately, the work was not evaluated.

2.4 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 2 Summary of Some Related Literature on Pothole and Bumps Detection System

S/No	Reference	Paper Title	Achievements	Technique(s) Used	Drawbacks/Limitations
1.	(Srivastava et al., 2018)	Analysis and Improvements on Current Pothole Detection Techniques	Road maintenance system which uses Basic Ultrasonic Sensors,	Internet of Things and Raspberry Pi and a Mobile phone	Cloud storage needed for storing GPS data

			Raspberry Pi and A Mobile Phone was implemented		
2.	(Ghadge et al., 2016)	Machine Learning Approach for Predicting Bumps on Road	Bumps Detection System(BDS) which uses Accelerometer for pothole detection and GPS for plotting the location of potholes on Google Map	Smart- phone based method which uses a Accelerometer and GPS sensors to analyze the road conditions.	System was trained to only detect potholes, other speed limit objects like bumps are not detected
3.	(Kamalesh et al., 2021)	An Intelligent Real Time Pothole Detection and Warning System for Automobile Applications Based on IoT Technology	Designed a simple IoT based low-cost portable and economically affordable device to detect the potholes and intimate the damaged scenario to the corresponding authorities.	The system was successfully implemented using Raspberry Pi3 Single Board Computer (SBC) to capture, analyze the images and for email communication protocol.	The system is only implementable on customized motorbikes. Cannot be implemented on other vehicles.
4.	(Egaji et al., 2021)	Real-time machine learning-based approach for pothole detection	Two Mobile Apps were designed, the first records the accelerometer, gyroscope and GPS data, and the second app help in data labelling.	Random Forest for binary classification of dataset, GPS for locating the pothole position	Classified image into two classes only. Today's road objects are multiclass in nature.
5.	(Wu et al., 2020)	An Automated Machine-Learning Approach for Road Pothole Detection Using Smartphone Sensor Data	Smartphone was used to design an automatic pothole detection system utilizing the built-in vibration sensors and global positioning system receivers in smartphones.	Machine Learning Classifiers were used to classify road traffic objects. Random Forest outperformed other classifies and was used to design the mobile App for automatic pothole detection.	The accuracy of 75% is not reliable and therefore needs to be enhanced.
6.	(Van Khang & Renault, 2019)	Cooperative Sensing and Analysis for a Smart Pothole Detection	introduced a lightweight architecture to sense and analyze potholes based on data collected with	The researchers improve some algorithms for real-time road-anomaly detection using smartphones using Z-Thresh, Z-Diff, STDEV	Two-way data processing needs a lot of energy consumption.

			smartphones.	and DVA	
7.	(A. Sha, Guarav Sharma, 2021)	Smart Implementation of Computer vision and ML for Pothole Detection	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
8.	(Anand et al., 2020)	Intelligent Vehicle Speed Controlling and Pothole Detection System	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

3. RESEARCH GAPS

From the literature in summary in table 2. The following drawbacks are identified from the reviewed literatures. These limitations would be used as research gaps which for researchers.

1. There is need to evaluate the performance of these machine learning algorithms with the aim of identifying the one with best;
2. There are still high number of false positive and needs to be reduced.
3. The highest accuracy of 97.6% needs to be improved;
4. The system is limited to detect potholes, other anomalies like bumps are ignored by the system. However, bumps are also among the major causes of car damages and sometimes accidents (Ghadge et al., 2016).

4. CONCLUSION

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 signs. 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.

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