REVIEW ARTICLE
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A Review of Computer Vision–Based Traffic Controlling and Monitoring

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ABSTRACT

Due to the rapid increase of the population in the world, traffic signal controlling and monitoring has become an important issue to be solved with regard to the direct relation between the number of populations and the cars' usage. In this regard, an intelligent traffic signaling with a rapid urbanization is required to prevent the traffic congestions, cost reduction, minimization in travel time, and CO2 emissions to atmosphere. This paper provides a comprehensive review of computer vision techniques for autonomic traffic control and monitoring. Moreover, recent published articles in four related topics including density estimation investigation, traffic sign detection and recognition, accident detection, and emergency vehicle detection are investigated. The conducted survey shows that there is no fair comparison and performance evaluation due to the large number of involved parameters in the abovementioned four topics which can control the traffic signal controlling system such as (computation time, dataset availability, and an accuracy).

Index Terms: Traffic signaling system, Intelligent traffic, Computer vision, Traffic congestion, Traffic monitoring, Review.

1. INTRODUCTION

Number of cars has significantly increased nowadays, [1], [2] consequently, traffic congestion problem has been arise around the world [3]. Subsequently, vehicle clashing and crashing and dramatic increase of CO2 emission per year [4] are threatening sustainable mobility of future [5]. Furthermore, traffic control needs man power to be controlled [6]. The traffic control devices are time dependent and designed to flow the traffic in all directions. On top of that, sometimes during turning the lights from green to red causes traffic deadlock in a direction without having a noticeable flow in the other direction [7].

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Congestions caused by traffic signals could negatively impact on economy in terms of transportation due to fuel [8], time expenditure [9], and air pollution [10]. Moreover, injuring even sometimes death caused by accidents happened in deadlock traffics [8], on the other hand, reducing congestion may have economic, environmental, and social benefits.

In general, to make the optimization problem manageable, several assumptions have to be made. The main problem that arises is that these assumptions deviate and sometimes do so significantly from the real world. Meanwhile, many factors have effects on drivers in real world traffics such as on driver's preference interactions with vulnerable road users (e.g., pedestrians, cyclists, etc.), weather and road conditions [11].

On the other hand, computer vision has an important role in managing and controlling traffic signals with great success [6], [12]. The best way to control traffic flow in big and busy cities is to utilize intelligent traffic signal [6], the system has ability to approximately evaluate density estimation,

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traffic signals detection and recognition, emergency and police car detection, and accident detection. Even though a better infrastructure can improve the traffic flow [13]. Usually in quiet intersections, the traffic is controlled by human or system controls [6]. In most congestions, cameras have been put for purposes other than traffic control, such as security, vehicle detection, and arrangement [14]. These cameras can be utilized for the reason of analyzing traffic scenes simply by employing specific hardware. The main advantage is that there is no need for replacing the CCTVs. The main objective of this survey is to fill the research gap that exists in the field of traffic signal controlling and monitoring.

The importance of this survey is to propose some technique based on computer vision for reducing the road congestion and keeping the environment green and public health. In this study, different approaches based on computer vision for traffic signaling controls are reviewed. For this purpose, the literatures over the period January 2015–January 2022 are surveyed. The structure of this review is as follows: Section I provides an introduction to the traffic and its problems. Background of traffic management addressed in Section II. In Section III, a literature review is provided for the existing solution of the intelligent traffic signaling. Section IV provides a discussion of review of the existing solutions. Finally, conclusion remarks are presented in last section.

2. REVIEW STRATEGY

This review is aimed in analyzing the recent literature for the vision-based methods for traffic controlling and managing, which have been published from January 2015 to January 2022 in terms of journal papers and conference proceedings. The reviewed papers were chosen after an extensive manual search of databases including IEEE Xplore, Springer, Elsevier, and Google Scholar. Keywords used to explore the databases are shown in Table 1. In addition, vision or image processing keywords are selected as the main keywords in the title of papers. Moreover, one of the sub search keywords has been used with main keyword to find the studies in the above mentioned period.

3. URBAN TRAFFIC LIGHT SYSTEM

Usually, each traffic light contains three color lights precisely, green, yellow, and red lights. They are put in the four parallel and perpendicular directions [15]. Fig. 1 shows a common intersection that formed by two perpendicular and parallel lanes.

Globally, the meaning of the lights for the drivers is as follows, green light means that the current lane has right to move forward meanwhile all other three directions are red which means they are not allowed to flow [11]. Besides, models of controlling traffic signaling and monitoring using computer vision required CCTV camera to acquisition images from the live traffic intersection. The simulation of traffic controlling in the cross road is shown in Fig. 2 [16].

4. LITERATURE REVIEW

To improve traffic signaling control and monitoring, scientists and researchers proposed many methods based on machine vision. Computer vision-based architecture of traffic signaling controlling and monitoring includes image acquisition, preprocessing and applying advance computer vision techniques density estimation, traffic sign detection and recognition, accident detection, and emergency vehicle detection. In this review, papers are randomly selected according to proposed methods in the recent years (between January 2015 and January 2022) for controlling and monitoring traffic signals.

4.1. Density Estimation

Density estimation is a key aspect for automatic traffic signaling control and reducing congestion in the intersection areas. Different approaches by reviewers to estimate traffic density are detailed below:

Table 1: Search parameters of the literature review

Date range	Database	Main Keywords (OR)	AND/Sub Search Key-words
January 2015–January 2022	IEEE Xplore Springer Elsevier Google Scholar	Vision Image Processing Machine Learning Deep Learning	Traffic Controlling Traffic Density Traffic Congestion Crowd Detection Accident Accident Detection Accident Identification Emergency Vehicle Traffic Sign

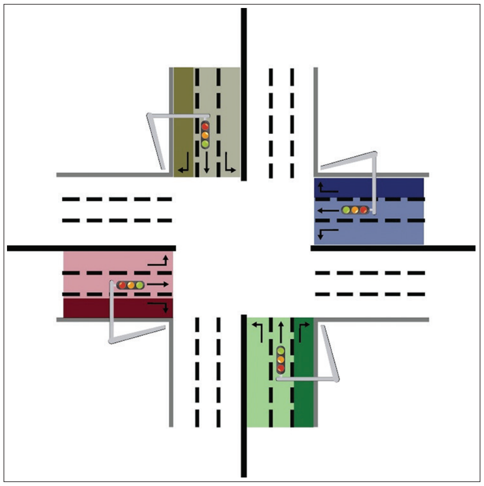

Fig. 1. Four road lanes intersection.

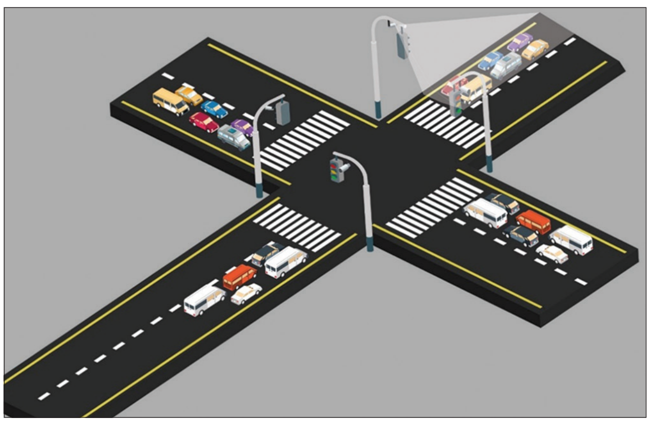

Fig. 2. Vision-based crossroad model.

Garg *et al.* [17] presented the approach for estimating traffic density based on vision which forms the fundamental building block of traffic monitoring systems. Due to the low accuracy of vehicle counting and tracking of existing techniques, the sensitivity to light changes, occlusions, congestions, etc. are made. Moreover, the authors addressed another problem of existing holistic-based methods by difficulty of implementation in real-time because the high computational complexity is required. To handle this issue, density is calculated using block processing approach for busy road segments. The proposed method involves two steps including marking of region of interest (ROI), generating block of interest, and background construction in the first step. Recurring process has been applied in the second step which involves background update, occupied block detection, shadow block elimination, and traffic density estimation. Finally, the proposed methods are evaluated and tested using the TrafficDB dataset.

In Biswas *et al.* [1] density estimated based counting cars, Background Subtraction (BS) method and OverFeat framework are implemented. The accuracy of the proposed system is evaluated by manual counting of cars. Furthermore, the comparative study was conducted before and after outperforming OverFeat framework. Average accuracy reached 96.55% after applied OverFeat Framework from 67.69% average accuracy for placemeter and 63.14% average accuracy for BS, respectively. Furthermore, this study confirmed that the OverFeat Framework has another application area. The advantages and shortcomings of the BS and six individual obtained traffic videos have used for analyzing OverFeat Framework with regarding different perspectives such as camera angles, weather conditions, and daily time.

Biswas *et al.* [3] implemented single shot detection (SSD) and MobileNet-SSD for estimating traffic density. For this purpose, 59 individual traffic cameras used for analyzing the SSD and MobileNet-SSD framework advantages and shortcomings. Moreover, two algorithms are compared with manually estimated density. The SSD framework demonstrates significant potential in the field of traffic density estimation. According to their experiment, the significant accuracy of detection achieved, numerically speaking the precisions were 92.97% and 79.30% for SSD and MobileNet-SSD, respectively.

Bui *et al.* [18] developed a method for analyzing traffic flow, advanced computer vision technologies have been used to extract traffic information. For finding traffic density estimation in intersections data acquired from video surveillance. Moreover, YOLO and DeepSORT techniques turned for the detection, tracking, and counting of vehicles have enveloped to estimate the road traffic density. To evaluated the proposed method, data collected in a real-world traffic through CCTV during 1 day.

A new technique for estimating traffic density utilizing a macroscopic approach has been developed by Kurniawan *et al.* [19]. The proposed method contains two parts including background construction and a traffic density estimation algorithm. The background construction obtained from detected non-moved vehicles in the front or behind vehicles. Moreover, background of the image founded using the edge detection technique. Density estimated by founding the ration between the number of ROI containing object and the total number of ROI.

Eamthanakul *et al.* [20] proposed a method-based image processing techniques for congestion detection. The technique contains three parts: (1) Image background substation used for separating vehicles from the background, (2) Morphological techniques applied for removing the image noises, and (3) traffic density calculated from the obtained image from CCTV. Finally, the results of the process are sent to transport plan database.

4.2. Traffic Sign Detection and Recognition

Traffic sign recognition plays a key role in driver assistance systems and intelligent autonomous vehicles. Furthermore, it can be helpful for automatic traffic signals which leads to prevent pass across the intersections in the case of read signals.

Novel approaches proposed in Berkaya *et al.* [21] for traffic sign detection and recognition. A new method developed to detect traffic sign under the name of circle detection algorithm. In addition, RGB-based color thresholding technique was proposed by Berkaya *et al.* [21]. Moreover, three algorithms have been used to recognize traffic signs including histogram of oriented gradients (HOG), local binary patterns and Gabor features are employed within a support vector machine (SVM) classification framework. The performance of the proposed methods for both detection and recognition evaluated on German Traffic Sign Detection Benchmark (GTSDB) dataset. Based on the obtained results from experiments, the proposed system better than the reported literatures and can be used in a real-time operation.

Yang *et al.* [22] presented a method for traffic sign detection and recognition, the method includes three steps. Thresholding of HSI color space components used to segment image in the first step. Applying the blobs extracted to the first step for detecting traffic signs in the second step. The contribution of their method in the first step, machine learning algorithms not used classify shapes instead of this invariant geometric moments have been used. Second, inspired by the existing features, new method has been proposed for the recognition. The HOG features have been extended to the HSI color space and combined with the local self-similarity (LSS) features to get the descriptor. As a classifier, random forest and SVM classifiers have been tested together with the new descriptor. GTSDB and the Swedish Traffic Signs (STS) data sets have been used to test the proposed system. Finally, the results of the presented technique compared with existing techniques.

Salti *et al.* [23] combined solid image analysis and pattern recognition techniques for detecting traffic sign in mobile mapping data. The system designed base on interest regions extracting which makes a significant with other existing systems that sliding window detection have been used. Furthermore, with having challenging conditions such as varying illumination, partial occlusions, and large scale variations, the proposed system good performance demonstrated. Three variant category traffic signs aimed to detect including mandatory, prohibitory and danger traffic signs, according to the experimental setup of the recent GTSDB competition. With having a very good performance of the proposed method in the online competition, the proposed method challenging dataset mobile mapping of Italian signs the pipeline has been evaluated and showed its successfully be deployed in real-world mobile mapping data.

In Du *et al.* [24] designed the robust and fast performance classifier-based detector. They addressed two algorithms for detection and classification. First, aggregate channel features based on three types of features, which including the color feature, the gradient magnitude, and gradient histograms proposed. Second, boosted trees classifier multiscale and multiphase detector have been proposed based on Real AdaBoost algorithm. The obtained results from experiments of this study show high average-recall and speed which is evaluated on Daimler, LISA, and LaRA datasets.

Real-time traffic signs' detection and recognition are necessary for smart vehicles to make them more intelligent. To deal with this this issue. Shao *et al.* [25] are proposed a new approach that includes two steps; in the first one acquitted images from the road scene converted to grayscale images. Then simplified Gabor wavelets (SGW) filter has been applied to the optimized parameters of grayscale images. Furthermore, traffic sings bounded by edge detection which helps preparing the obtained result to the next process. In the second, the ROI extracted using the maximally stable extremal regions algorithm and the superclass of traffic signs are classified by SVM. To classify their subclasses, the traffic signs convolution neural networks (CNN) with input by simplified Gabor feature maps, where the parameters were the same as the detection stage is used. Finally, the proposed method tested on GTSDB and CTSD datasets and the results obtained from the experiments show that the method is fast and accurate by 6.3 frames per second and 99.43%, respectively.

Berkaya *et al.* [21] presented new ideas to provide colorful graphics to improve traffic in terms of object recognition and problem detection. Two digital image processing methods, namely, Circle Detection Algorithm and RGB which based on the simplest image segmenting method have been improved to develop the ability of traffic sign detection. The classification framework, namely, SVM has been formed through assembling three main attributes including Gabor features HOG, and local binary patterns in the smart system. The presented technique is validated by German Traffic Sign Detection and Recognition Benchmark datasets, correspondingly. According to the practical results, their technique is by far more efficient than the quoted approaches in this paper; the results are also aligned with the real time operation.

A new approach for detecting and recognizing traffic signs proposed in Ellahyani *et al.* [26] which includes three main steps. Thresholding of HIS has been used to segment the image based on components of color spaces in the first step. It followed by applying blobs by the result of extracted from the former step. Then, the traffic signs recognition performed for the detected signs in the last step. Moreover, in their study, two different approaches used to classify signs. Instead of machine learning algorithms, invariant geometric moments used to classify shapes in the first step. Second, inspired by the existing features, new ones have been proposed for the recognition. HSI color space taken from the HOG features and combined with the LSS features to get the descriptor while used in the proposed algorithm. Then, last test has been done based machine learning algorithms which are random forest and SVM classifier. Finally, the performance of proposed method evaluated and tested on German Traffic Sign Recognition Benchmark (GTSRB), GTSDB, and STS datasets.

Convolutional Neural Networks (CNN) machine learning algorithm is applicable for object recognition by having power full recognition rate and less time required for execution. In Shustanov and Yakimov [27] implemented traffic sign recognition using CNN. Furthermore, several architectures of CNN compared together. Meanwhile, Tensor Flow library is used for training and massively parallel architecture for multithreaded programming CUDA. The entire procedure for traffic sign detection and recognition is executed in real time on a mobile GPU. Finally, their method efficiency evaluated on GTSRB dataset and it is obtained very good result by 99.94% for classification images.

4.3. Accident Detection

A main aspect of traffic monitoring is the identification and tracking of vehicles. Monitoring vehicles helps to report and detect in the situation of the traffic junctions. One of the main aspects of traffic monitoring is the identification and tracking of vehicles. In this section, accident prediction and detection approaches are faced.

Tian *et al.* [28] developed a Cooperative Vehicle Infrastructure Systems (CVIS) and proposed machine based-vision that can be used to detect car accident automatically. The study includes two phases; CAD-CVIS database has been created to improve the accuracy of accident detection in the first phase. CAD-CVIS dataset with regarding different traffic situations consists of various types of accidents, weather conditions and accident location. In the second phase, to detect accident deep neural network model YOLO-CA based on CAD-CVIS and deep learning algorithms developed. Moreover, to improve the performance of the model for detection small objects Multiscale Feature Fusion and loss function with dynamic weights utilized. The results showed the proposed method faster than the previous methods, it can detect car accident in milliseconds with a very good average precision by 90.02%. Finally, the proposed methods compared with existing methods, and the results determined accuracy improved and real-time over other models.

A neoteric framework proposed for detecting accident in Ijjina *et al.* [29]. For accurate object detection, Mask R-CNN capitalized in the proposed framework by an efficient centroid-based object tracking algorithm for surveillance footage. The basic idea is to determine an accident after overlapping vehicles together are speed and trajectory anomalies in a vehicle after an overlap with other vehicles. This framework was found to be dominant and paves the way to the development of general-purpose vehicular accident detection algorithms in real-time. The framework tested and evaluated by the proposed dataset with the different weather condition.

In Saini *et al.* [30], a vehicle tracking technique based on image processing is developed without applying background subtraction for extracting the ROI. Instead, a hybrid of feature detection and region matching approach is suggested in their study, which is helpful for estimating the trajectory of vehicles over consequent frames. Later, as the vehicle path through an intersection, the tracked direction is monitored for the occurrence of any specific event. It is found that the proposed method has capability to detect an accident between two vehicles.

Wenqi *et al.* [31] proposed the TAP-CNN model for predicting accident based on CNN in the highways. Traffic state and CNN model are described by some accident factors such as traffic flow, weather, and light to build a state matrix. In addition, the way of increasing TAP-CNN model accuracy for predicting traffic accident different iterations are analyzed. Accident data collected for inflected learning and evaluation of the model. Finally, the experimental results show that the proposed model named TAP-CNN is more effective than the traditional neural network model for producing traffic accidents.

Dogru and Subasi [32] presented an intelligent system for accident detection in which vehicles exchange their microscopic vehicle variables with each other. Based on the vehicle speed and coordinates, data collected from vehicular ad-hoc networks (VANETs) simulated model in the proposed system and then, it sends traffic alerts to the drivers. Furthermore, it shows how to use machine learning methods to detect accidents on freeways in ITS. Two parameterizes help to analyze and detect accident easy which are position and velocity values of every vehicle. In addition, OOB data set has been used to test the proposed method. Finally, the results show that the RF is better than ANN and SVM algorithms by with 91.56%, 88.71, and 90.02% accuracy, respectively.

Vision-based algorithms have been used in Yu *et al.* [33] to detect traffic accident including an ST-IHT algorithm for improving the robustness and sparsity of spatiotemporal features and weighted extreme learning machine detector for distinguishing between traffic accident and normal traffic. Furthermore, a two-point search technique is proposed to find a candidate value adaptively for Lipschitz coefficients to improve the tuning precision. For testing and evaluating the proposed method 30 traffic videos collected from YouTube website. Finally, the results show that the proposed method performance for detecting a traffic accident outperforms other existing methods.

Accelerometer is a widely employed method that used to detect a crash. In this research work [34], after calibration of accelerometer value of acceleration is use to detect an accident. Due to the limitation of accelerometer accuracy and providing the efficient accident detection, CNN machine learning algorithm is tuned. For detecting an accident, image classification technique is used; however, CNN takes a lot of time, data, and computing power to train. Transfer learning methods have been innovatively applied to alleviate these problems and for the accident detection application, which involves retraining the already trained network. For this purpose, Inception-v3 classifier that developed by Google for image was incorporated. Finally, the proposed method efficiency compared with the traditional accelerometer-based techniques for detecting accident by 84.5% of accuracy for transfer learning algorithm.

4.4. Emergency Vehicles Detection

The success of law enforcement and public safety relies directly on the time needed for first responders to arrive at the emergency scene. Emergency cars include ambulance, firefighter, and police car. Many methods are proposed to detect emergency cars and some of them as example are reviewed in this section.

In Borisagar *et al.* [35], two methods of computer vision are used to detect and localize the emergency vehicle. The used methods including object detection and instance segmentation. The proposed method implementation includes Faster RCNN for object detection and Mask RCNN for instance segmentation. The results show that the proposed method is accurate, most importantly, and suitable for emergency vehicle detection in disordered traffic conditions are deliberated. In addition, a custom dataset used for detecting emergency vehicles which contains 400 images and labeled using the label me tool.

Roy and Rahman [36] are proposed a model for detecting emergency cars from CCTV footage such as ambulance and fire-fighter on a heavy traffic road. In this model, priority given to these cars and clearing the emergency lane to pass the traffic intersection. For traffic police, sometimes deciding opening the specific lane for emergency vehicles is difficult or even impossible. Deep CNN and COCO dataset have been used for automated emergency car detection. The result of presented method for detecting and identifying all kinds' emergency vehicles generally is reasonable.

E. P. Jonnadula and P. M. Khilar [37] are presented a hybrid architecture for detecting emergency vehicles by combining features of image processing and computer vision. Also, search space decreased by using region of interest.

Prediction of ambulance helps to decrease the number casualty on the real traffic in case of having emergency situation on the road. To cover this problem, Lin *et al.* [38] presented a novel approach-based machine learning techniques and features are extracted using the multi-nature which can extract ambulance characteristics on demand. Furthermore, they experimentally evaluate the performance of next-day demand prediction across several state-of-the-art machine learning techniques and ambulance demand prediction methods, using real-world ambulatory and demographical datasets obtained from Singapore. Finally, various machine learning techniques used for different natures and SCDF-Engineered-Socio dataset have been used to show the proposed method accuracy.

The existing traffic light system is a lack of information in emergencies such as ambulances, firefighters, and police when a car is in. Suhaimy *et al.* [39] developed an embedded

Table 2: Proposed methods in literature reviews

Type of traffic management	Reference (s)	Algorithm (s)	Dataset (s)	Accuracy %	Contribution (s)
Density Estimation	[17]	Block Variance	The TrafficDB	93.70	Traffic density estimation with the low computational cost
	[1]	Background Subtraction, over feat framework, and place meter	ImageNet	96.55	Defining ROI by over feat framework
	[3]	Detection (SSD) and MobileNet-SSD	Data collected from cameras with different places	92.97 (SSD), 79.30 (MobileNet-SSD)	New path opened for real time traffic density estimation
	[18]	YOLO and DeepSORT	Collected data from CCTV	87,88 (Day, Congestion) 93,88 (Day, Normal) 82,1 (Night, Normal)	Detecting, tracking and counting vehicles
	[19]	ROI and edge detection	-	N/A	New technique developed for estimating traffic density
	[20]	Background subtraction and morphological techniques	-	N/A	Traffic density estimated
	[40]	CNN	UCSD	99.01	Traffic density estimation model proposed based CNN and computer vision
Traffic Sign Detection and Recognition Approaches	[22]	HSI, HOG, LSS, and SVM	GTSDB, CTSD	98.24 (GTSDB), 98.77 (CTSD)	Developed Circle detection algorithm and an RGB-based color thresholding technique
	[21]	HOG, LSS, Random Forest, and SVM	GTSDB	97.04	In the first step, machine learning algorithms not used classify shapes instead of this invariant geometric moments have been used. Second, method has been proposed for the recognition
	[23]	ROI, HOG, SVM, and Context Aware Filter	GTSDB	99.43 (Prohibitory) 95.01 (Mandatory) 97.22 (Danger)	Online detecting mandatory, prohibitory and danger traffic signs
	[24]	Aggregate Channel Features and Boosted Trees Classifier	Daimler, LISA and LaRA	84.314 (Daimler), 90.33 (LISA), 92.048 (LaRA)	Proposed the high average-recall and speed method
	[26]	HOG, LSS, and SVM	GTSRB, GTSDB and TST	97.43	Shapes classified byusing invariant geometric moments
	[25]	SGW and SVM	GTSDB and CTSD	99.43	Speed of detection and classification improved which is more than 6 frames per second
	[27]	CNN	GTSRB	99.94	CNN process described
	[41]	Proposed model named CapsNet	TL_Dataset		The proposed CapsNet is employed for traffic sign recognition.
Accident Detection	[28]	Deep neural network model YOLO-CA	CAD-CVIS	90.02	CAD-CVIS dataset created and the proposed method more fast and accurate
	[29]	Mask R-CNN	Proposed	71	Developing vehicular accident detection algorithms in real-time
	[30]	Hybrid of feature detection and Region matching	Real world dataset	N/A	Accident detection between two vehicles
	[31]	CNN	Accident data collected	78.5	Accident predicted using CNN
	[32]	ANN, SVM, and Random Forests (RF)	OOB data set	91.56 (RF), 88.71 (ANN), 90.02 (SVM)	The proposed method can provide estimated geographical location of the possible accident

(Contd...)

Table 2: *(Continued)*

Type of traffic management	Reference (s)	Algorithm (s)	Dataset (s)	Accuracy %	Contribution (s)
	[33]	ST-IHT, Spatio-Temporal Features and W-ELM	Collected dataset	87.4±0.3 (SVM), 94.3±0.2 (ELM), 95.5±0.3 (W-ELM)	(i) Robust Fractures extraction proposed based on OF-DSIFT and ST-IHT (ii) detect imbalance between traffic accident and normal traffic
	[42]	YOLOv4	video sequences collected from YouTube	N/A	presents a new efficient framework for accident detection
Emergency Vehicles Detection	[35]	Faster RCNN and Mask RCNN	Custom dataset	81 (Object Detection), 92 (Instance Segmentation)	The computational and accuracy for emergency vehicle detection are suitable
	[36]	Deep convolutional neural network	COCO	97.97	Detecting and identifying all kinds emergency cars
	[37]	YOLO + ResNet	COCO	N/A	Hybrid architecture presented for detection of emergency vehicles in a real time
	[38]	SVR, MLP, RBFN, and LightGBM	SCDF-Engineered-Socio	N/A	Varying degrees to the model training in LightGBM
	[39]	MFCC-SVM	-	97	Effectively distinguish audio events from audio signals

SSD: Single Shot Detection, CNN: Convolution neural networks, HOG: Histogram of oriented gradients, LSS: Local self-similarity, SVM: Support vector machine, GTSDB: German Traffic Sign Detection Benchmark, and GTSRB: German Traffic Sign Recognition Benchmark

Table 3: Used datasets

Type of Traffic Management	Used in References	Dataset (s)	Type	No. of Images
Density estimation	[17]	The TrafficDB	Image	-
	[1]	ImageNet	Image	3.2 million
	[3], [18]	Data collected from cameras with different places		-
	[40]	UCSD	Video	-
Traffic sign detection and recognition approaches	[21], [22], [23], [25], [26]	GTSDB	Image	50, 000
	[24]	Daimler	Image	5,000
	[24]	LISA	Video	-
	[24]	LaRA	Video	-
	[26], [27]	GTSRB	Image	900
	[41]	TL_Dataset	Image	46,000
Accident detection	[28]	CAD-CVIS	Video	-
	[29], [30], [31], [33], [42]	Proposed, real, and collected data		-
	[42]	YOLOv4		
Emergency vehicles detection	[35], [43]	Custom dataset		-
	[36], [37]	COCO		328,000

GTSDB: German Traffic Sign Detection Benchmark, GTSRB: German Traffic Sign Recognition Benchmark

machine learning application, including acquisition of data, features extraction, different algorithms exploration, tuning, and deploying the model to a good output model in a simulation application. Specifically, a classifier of ambulance siren sound into “Ambulance Arrive” and “No Ambulance Arrive” has been developed, which is the traffic light system could be used to track an ambulance’s arrival in an emergency. This paper suggests an approach based on Mel-frequency spectral Coefficients-SVM (MFCC-SVM) on MATLAB R2017b tools.

5. DISCUSSION

According to the results of this review, several attempts have been made to develop intelligent traffic controlling vision-based methods. Some challenges can be seen when researchers try to develop vision based automatic traffic signals. One of the challenges is that there is no available framework to cover all traffic problems because huge amount of data and computational time are required. Another challenge is the power consumption to get real traffic data to testing their proposed methods in the different weather conditions. The third challenge is the lack of standardized dataset for testing and training methods. The results show that there is no any comprehensive dataset for traffic controlling and monitoring. For example, in density estimation, most of the researchers have created their own datasets while in traffic sign detection and recognition; they have used some publicly available datasets such as (GTSDB and GTSRB). On the otherhand, both the accident and emergency vehicle detection methods have only collected and prepared (customized) real data which captured by CCTV cameras. Finally, current systems while studied in the literature provide a low-cost solution for traffic applications in the expense of the system accuracy and they are applicable.

5.1. Survey of Technique's Summary

According to the literature survey, researchers have proposed and developed many approaches for controlling and monitoring signal system based on computer vision algorithms. In Table 2, presenting methods for each survey topics associated with a summary of their (methods, datasets, and contributions). The reason that why the performance of the reviewed methods is not evaluated is a non-availability of a common datasets.

5.2. Datasets

For testing and evaluating the proposed methods, researchers worked on the public datasets and on their collected datasets. The used datasets are described in Table 3.

6. CONCLUSION

In recent years, reducing road congestion has become a key challenge because of the threatening rise in the number of vehicles on the roads. In this review, the existing studies on autonomic traffic controlling and monitoring are reviewed in the computer vision community. Furthermore, computer vision is considered as the areas with the most studies are for the future technologies. The intelligent traffic systems perceive the density estimation investigate, traffic sign detection and recognition, accident detection, and emergency vehicle detection. Furthermore, name of the used datasets in the reviewed papers are presented. The main gap that founded in this review is a non-availability of dataset for traffic controlling and monitoring. Finally, intelligent traffic systems can play a key role in reducing congestion in the intersection areas and traffic flow management. The conducted survey indicates the accuracy finding of each method as described in Table 2. This research work could be having a potential impact for further researches in the same field of study. Various challenges such as (weather conditions, lighting, and traffic patterns) can be considered with all techniques based on computer vision and machine learning methods. Consequently, these conditions will improve our survey in the future work.

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