Nighttime Vehicle Detection Methods Based on Headlight Feature: A Review

Shahnaj Parvin, Md. Ezharul Islam, and Liton Jude Rozario

Abstract— **Vehicle detection is used for detecting vehicles on roads, highways, parking, or any other place. It plays a key function in the control and management of traffic. In the Intelligent Transportation System (ITS), nighttime identification and recognition of moving vehicles are the most challenging and important processes. The quantity of vehicles on the road has grown significantly in recent years, and as a result, road accidents are constantly occurring. Accidents are more likely to happen at night, according to statistics. The whole vehicle body remains invisible at night due to the absence of illumination. Visibility at night is the major issue for safe driving. The appearance of vehicle headlights at night conditions plays a key role. When driving at nighttime, drivers usually turn on high-intensity headlights, resulting in annoyance for drivers driving from the opposite direction. For oncoming vehicles, these high-intensity lights generate glare and induce temporary blindness. For this reason, most accidents happen at nighttime. In solving this problem, nighttime vehicle detection is of great significance. The main focus of this review paper is to examine, present, and summarize the various proposed methods and techniques, and future directions so that new methods of vehicle detection can be developed which are to circumvent accidents during the night and keep distance between the moving vehicles. Hopefully, this review paper will be helpful for future research and consideration either for developing improved algorithms or guidance or both.**

Index Terms— **Vehicle Detection, Nighttime, Headlight, Headlight Detection, Headlamps, Headlight Pairing**

I. Introduction

VEHICLE detection is a crucial factor in the development of an intelligent transport system. The quantity of vehicles on the road is increasing every day [1], [2], [3]. In this manner, vehicle manufactures are giving topmost importance to vehicle safety. To ensure safety and reduce accidents, vehicle detection has become a prominent area of research [4], [5], [6]. Lack of alertness of drivers is the primary cause for the increase of striking numbers of accidents latterly influencing noticeable focus on Advanced Driver Assistance Systems (ADAS). That's why a key role of ADAS; spotting vehicles in front of one's own by employing computer vision know-how, has been a very popular research field over the preceding years [4], [7], [8]. To obtain valuable and relevant traffic information for the research purposes, such as vehicle tracking, vehicle count, vehicle trajectory, vehicle classification, vehicle speed, license plate recognition, and so on [3], [9], [10].

Statistically, most road accidents happen at night [11], [12]. At night, because of its light circumstances, the entire body of the vehicle is invisible. For safe driving, the big concern is perceptibility in the dark. Some careless drivers keep it up using high beams despite the very fact that the oncoming vehicle is assumed [4], [13], [14]. Vehicle headlights are designed to throw high beams and low beams in the night environment. The lower beams generate less intensity and the higher intensity is provided by high beams, which are utilized throughout the night [6], [14], [15].

The driver has to deal with fluorescence for a period as vehicles approach the opposing vehicle by flashing high-intensity light that may shut or blind the driver's eyes for a short period. Most accidents occur at night for this reason [2], [6], [16]. Therefore, vehicle detection at nighttime holds great significance for the enactment of protection features in vehicles.

To reduce night accidents, detection of the preceding vehicle (in the same direction), together with oncoming vehicles (in the reverse direction) is necessary [4], [13], [15], [17]. Vehicle detection and tracking are challenging for the illumination conditions have always been a difficult problem at nighttime. Several scientists have worked at night to identify and strive to progress within this area. They have introduced various imaging techniques and provided some of their vehicle detection strategy for the night based on vehicle headlights, taillights, and brake lights. The vehicles are visible by their brake lights, taillights, and headlights in poorly lit conditions. Therefore, nighttime spotting of vehicles, headlights, and brake/taillights are the most dependable attributes [2], [4], [11], [18].

In this review paper, the detection of nighttime vehicles based on the headlight has been incorporated as much research as possible. Many nighttime vehicle detection methods proposed previously have been reported in this paper. Most of them are focused on the algorithms and technologies used to detect vehicles. Therefore, the intention of this review paper is 1) to sum up modern vehicle detection methods by using images and/or video, 2) to compare and evaluate the performance of the approaches for different vehicle detection methodologies under different environments. We have categorized the studies of nighttime vehicle detection based on the headlights into three sections: (1) Image-based Nighttime Vehicle Detection (2) Nighttime Vehicle Headlights Intensity Control and (3) Image and

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Sensor-based Vehicle Detection.

The rest of the study is arranged accordingly: Section 2 outlines the headlights and its laws. The image-based nighttime vehicle detection is presented in section 3. In section 4, nighttime vehicle headlights intensity control is illustrated. Image and sensor-based nighttime vehicle detection techniques are discussed in section 5. The common approach for vehicle detection based on headlights is introduced in section 6, and lastly, the conclusion is presented in section 7.

II. Headlights and Its Laws

A headlight is a light source present in the interior of a vehicle to light up the road in the forward direction. Headlights are also frequently termed headlamps [19], [20]. The headlight arrangement is essential to create a low and a high beam where low beams provide onward and sideways illumination, with bounds on light focused to the eyes of other street users to regulate glare, and high beams deliver a bright, center-weighted delivery of light with no actual restraint of light focused to other passerby's eyes. Table 1 shows the basic distinctions between the low beam and high beam is given below [20], [21]:

TABLE I
Difference between Low Beam and High Beam

	Low Beam	**High Beam**
Source	the principal source of light	an additional source of illumination
Used for	utilized in regular at night driving	narrow roads or dark roads
Beam angle	the direction of ground/road	straight/upwards
Focus	short-range	long-range
Activation period	must constantly remain at a low or no light level	relatively short period/no other cars within 150 meters
Blind other drivers	no	yes
Light coverage	40 meters	100 meters

The law requires that the headlights be switched on if it is dark outside, typically from dusk to dawn.

Consider the use of high beams [22], [23]:

- countryside or mountain roads (switch high beams off when two vehicles are crossing each other)
- uncluttered freeways when no other vehicles are present
- streets and roads having no lights

Consider the use of low beams [22], [23]:

- Unfavorable weather makes visibility hard
- Driving in the mist
- Inside the range of 500 feet of another vehicle (several states want switching high beams to low beams when you are inside a fixed distance of a vehicle—lookup local headlight laws)
- Road signs specify a daytime headlight section

III. Image-based Nighttime Vehicle Detection

Nighttime vehicle detection continues to be a challenging research field [4], [7], [11]. The image-based nighttime vehicle detection approaches have been addressed in this section in detail. The image-based method employs a camera to capture images at night. To detect the presence of the vehicle, the image sequence is then processed [4], [18]. Moreover, detecting vehicles in images acquired from a moving platform is a tenacious task. Focusing on the headlights, several ways are presented for identifying and recognizing vehicles at night. The image-based nighttime vehicle detection methods have been broken down into some subsections dealing with headlights glare and temporary blindness. The related works of image-based nighttime vehicle detection based on headlights are given below.

A. Feature-based Approaches

Visibility varies in scale, shape, color, and appearance of vehicles. Various characteristics, such as color, symmetry, edge (horizontal/vertical), shadow, etc., have been used as significant indicators for vehicle detection [4], [12], [16], [24]. Feature-based methods are fast and convenient. Therefore, most researchers choose to use feature fusion in vehicle detection algorithms.

H. Fleyeh and Iman A. M [11] implemented an approach to identify vehicles at night using a camera. For training purposes, they have used the SVM classifier to detect vehicle headlights by recognizing their shapes. To confirm that the two headlights are of the same vehicle, they have also used a pairing algorithm developed to pair the headlights of a vehicle. During the span the vehicle is on the scene, a multi-object tracking algorithm (Kalman filters) [25], [26] is invoked while tracking vehicles. They have informed the accuracy of their suggested system is 97.9%, and the rate of vehicle recognition is 96.3%. Fig. 1 displays the block diagram of this work.

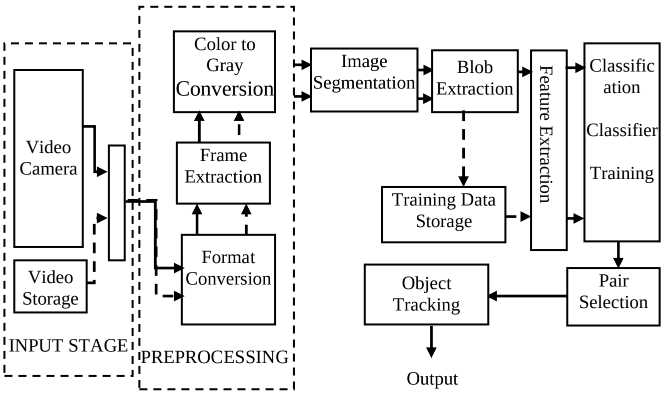

Fig. 1. Block diagram of the detection algorithm of H. Fleyeh and Iman A. M [11]

C. H. Hsia, Y. Kong, Y. K. Lin, and Y. R. Chien [27] developed a multi-feature technology that can be used to track vehicle headlights at nighttime. At first, the light source distribution is evaluated in each captured image, and the headlights are separated by length and width ratios. If two headlights meet the criteria, a distinction between vehicles is performed to avoid counting the same vehicle twice. The two headlights used a similarity analysis algorithm to determine whether space and colors are from the same vehicle.

D. Xiaodong, Liu D., Yang L., and Liu Y. [28] suggested a model based on Hough Transform for detecting night vehicles. The headlight features are acquired from a gray division which then divides the acquired features into connected areas and also extracts the edge of the light. Afterward, the circle is detected with the Hugh Transform [29], [30], [31] which determines the radius of the lamp and the position of the vehicle. When the vehicle lights finally come in pairs, the matching algorithm examines the location of the vehicle to see whether the positions match. The researcher reported the highest detection accuracy and a low false positive for their suggested method. Fig. 2 shows a flow diagram of the detection of the vehicles at night.

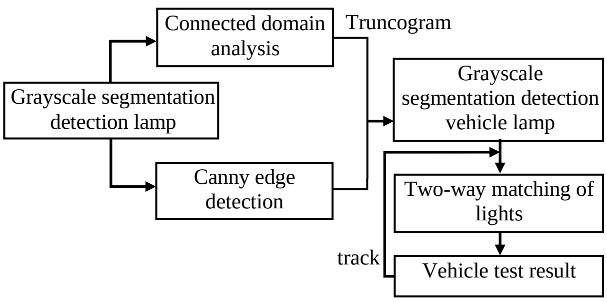

Fig. 2. Nighttime vehicle detection prototype of D. Xiaodong, Liu D., Yang L., and Liu Y. [28]

C. Rajkumar and S.K. Mahendran [32] introduced a method to reduce the outer light sources based on a grayscale image, dilation, and edge detection. The suggested method consists of two parts: a feature extraction system for the vehicle features and a vehicle detection system by minimizing the complex background light. Streetlights must be removed by changing the light parameters to correctly extract the vehicle from the lights. The proposed system has some steps. Initially, the image is transformed into a grayscale image, then dilated. After this, by using a canny edge detector, the edges of the objects are identified. Last, segmenting the image and monitor targeted vehicles in the image.

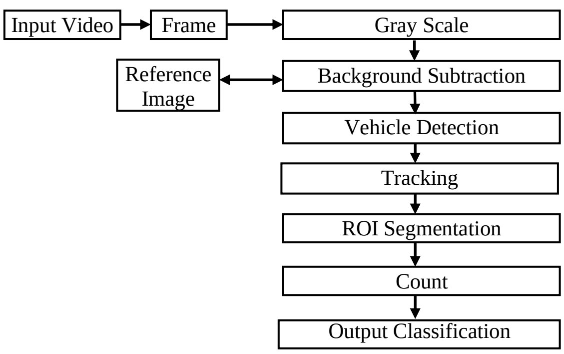

Fig. 3. Block diagram of the proposed system of Vaishali V., Thanuja T, and Priyadarshini J. [1]

Vaishali V., Thanuja T., and Priyadarshini J. [1] proposed a technique for nighttime vehicle detection, classification, and counting. They have used a feature method like a background subtraction algorithm, a tracking algorithm (blob analysis) [33], [34] for object tracking, vehicle classification using the correlation matching process [35] and counting vehicles through the ROI sensing line. The Kalman filter has been used to filter out the unwanted regions, and for vehicle detection, they have also used morphological operation techniques [36], [37]. They divided vehicles into three classes: smaller (e.g., car), medium-sized (e.g., van), and big vehicles (e.g., bus and truck). Fig. 3 shows the basic diagram of the proposed technique.

Yingfeng C., Xiaoqiang S., H. Wang, L. Chen, and H. Jiang [12] proposed an algorithm on Far-infrared (FIR) image [38], [39] for vehicle detection depending on visual saliency [40] and deep learning [41]. Initially, with visual saliency calculation, they eliminated non-vehicle pixels. They subsequently generated candidates utilizing prior information, including camera parameters and vehicle size. In the last stage, a deep networks classification has been used to authenticate the candidates that are created. They stated the detection rate is 92.3 %, which meets real-time application demands and the processing time is less than 40ms per frame. Fig. 4 shows their proposed flow diagram.

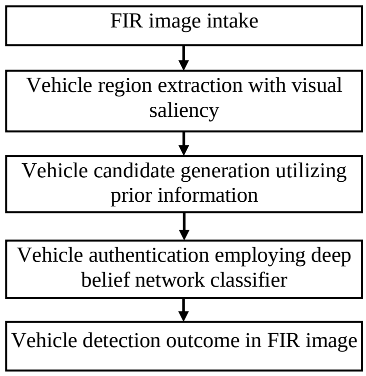

Fig. 4. Proposed flow diagram of Yingfeng C., Xiaoqiang S., H. Wang, L. Chen, and H. Jiang [12]

In [42], Sooksatra, S., Kondo T., Bunnun P., Yoshitaka A. proposed a unique algorithm to create 3D trajectories and reflections of the headlights on the road using both space and time. In different traffic views, 3D structures tensor have been used as forming characteristics to recognize the headlights. Their experimental findings indicated that the proposed strategy performs with the F1 score better than conventional methods (approximately 10%).

B. Segmentation and Threshold-based Approaches

An important step of every computer vision system is image segmentation. As a method of separating items of interest from the rest of the scene, it can be discussed. Various segmentation and threshold-based methods have been used as significant indicators for the identification of vehicles. Therefore, in-vehicle detection algorithms, most researchers prefer to use segmentation and threshold-based techniques.

Y. L. Chen and C.Y en Chiang [17] implemented a system for spotting vehicles in anterior of a camera-assisted vehicle at night driving. Their suggested approach has been applied to an embedded framework and used image segmentation techniques [43] to detect vehicles based on headlights and taillights and pattern analysis [44]. They have used the segmentation method centered on automatic multilevel thresholding [45], [46] to obtain the bright object. Their proposed night driver assistance system is installed and deployed on an ARM-Linux implanted platform. The suggested technique comprises the following phases: bright object segmentation, spatial clustering, rule-based vehicle recognition, distance estimation of the vehicle, vehicle collision warning, and signaling and controlling apparatus. Fig. 5 and Fig. 6 are shown the hardware and software architecture of the suggested system.

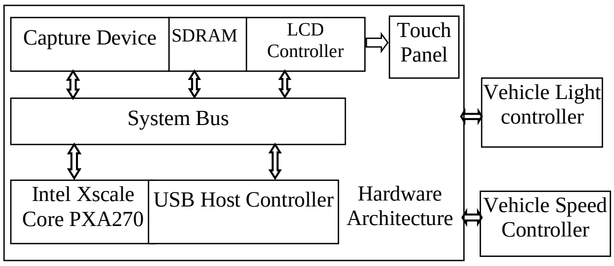

Fig. 5. Hardware architecture of Y. L. Chen and C.Y en Chiang [17]

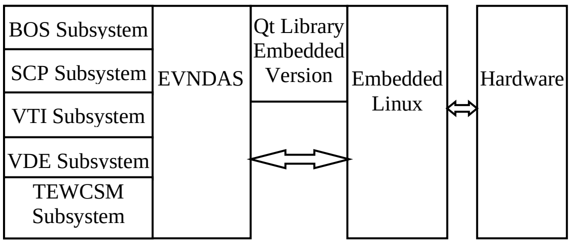

Fig. 6. Software architecture of Y. L. Chen and C.Y en Chiang [17]

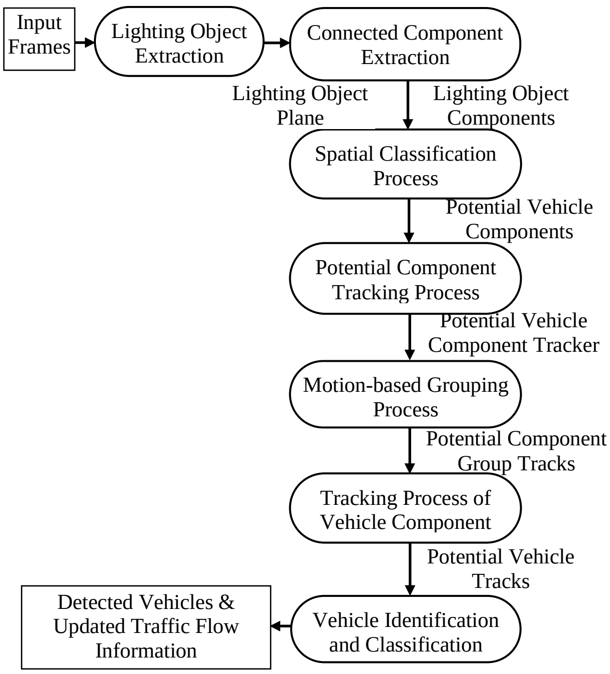

Fig. 7. Block diagram of the suggested nighttime traffic surveillance system of Y. L. Chen, B. F. Wu, H. Y. Huang, and C. J. Fan [10]

Y. L. Chen, B. F. Wu, H. Y. Huang, and C. J. Fan [10] proposed a vehicle identification and control system centered on automated multilevel histogram thresholding for light-object segmentation and to remove luminous objects from night traffic image sequences. A Spatial analysis and cluster method for likely motions of successive frames have been used for the assembly of illuminating objects in vehicle lighting clusters. Fig. 7, demonstrates the general process flow of the suggested night traffic surveillance system.

M. Taha, H. H. Zayed, Taymoor N., and M. E. Khalifa [7] introduced a system for nighttime detection and monitoring of moving vehicles. They have used automatic thresholding and connected component extraction [47], [48] for vehicle identification by detecting and locating vehicle lights. Then a rule-based component analysis [43], [49], [50] has been used to find vehicle light pairs to approximate vehicle positions and employs Kalman Filter [51] for the tracking process. They have reported that their technique in different nighttime conditions is viable and efficient for vehicle recognition, and the average tracking rates for both urban and highway are 96.27% and 95.76%. The flow diagram of the suggested approach is shown in Fig. 8.

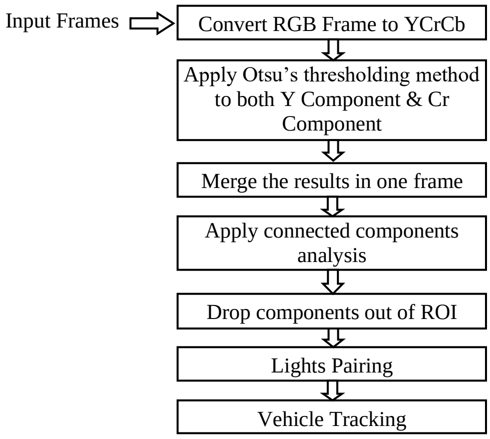

Fig. 8. Block diagram of the suggested method of M. Taha, H. H. Zayed, Taymoor N. and M. E. Khalifa [7]

Jacob V. P. [3] proposed a nighttime traffic surveillance approach for the detection and monitoring of moving vehicles. Initially, a speedy light object segmentation method centered on automatic multilevel histogram thresholding has been used to find light objects. Thereafter, the obtained light objects are subsequently processed by a spatial clustering and monitoring method which recognizes and examines the spatial and time-based characteristics of vehicle light patterns and recognizes moving vehicles in the night scenes of traffic as well. They have reported that their proposed system is more robust and reliable for nighttime vehicle detection.

V. H. Pham and D. H. Le [52] suggested an approach for vehicle detection and counting based on a two-stage system. They have used a headlight candidate extraction method based on the clustering-based segmentation k-means [53], [54], [55]. This technique has been used as a multi-threshold to segment the lowest level and highest intensity gray image of the traffic section. In the ROI, both single and paired headlights have been tracked. When the headlight pairs meet specified counting rules, a Kalman filter is utilized to track the detected headlights and to count decisions. The researchers reported that their system at nighttime is robust with different lighting circumstances and the system has achieved approximately 98% accuracy. Fig. 9 shows the prototype of the vehicle counting process.

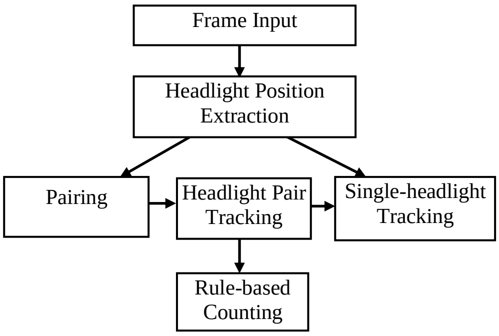

Fig. 9. Proposed vehicle counting method at nighttime of V. H. Pham and D. H. Le [52]

T. A. Vu, L. H. Pham, T. K. Huynh, and Synh V. U. H. [24] implemented an algorithm consisting of headlamp segmentation, headlamp identification, headlamp tracking, headlamp pairing, and vehicle classification for vehicle recognition at night. They have segmented bright lights depending on luminosity and color thresholds. The candidate headlamps have subsequently been identified and confirmed through headlight features such as location, centroid, and shape. They believed that their proposed technique is a fancy method because the headlights are combined using a trajectory tracking technique and the detection rate of the suggested system in nighttime traffic scenes is about 81.19%. The prototype of the suggested system is revealed in Fig. 10.

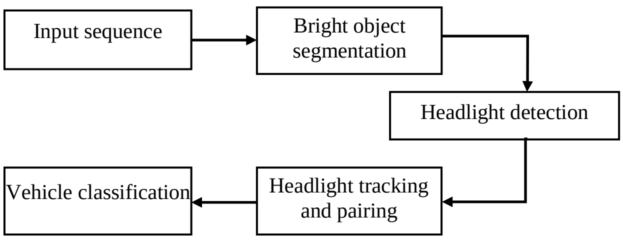

Fig. 10. System overview of proposed method of T. A. Vu, L. H. Pham, T. K. Huynh, and Synh V. U. H. [24]

S. Kanagamalliga, Dr. S. Vasuki, A. Kanimozhidevi, S. Priyadharshni, S. Rajeswari [56] suggested a system for nighttime vehicle spotting. Their proposed method has some steps. At first, the edges of the objects have been detected by using a canny edge detector [57], [58]. The bright object extraction in the segmentation process has been done by the thresholding techniques. Thereafter, the headlights of the vehicles have been tracked based on the connected component labeling technique [59], [60] and the headlights have been paired by the bidirectional reasoning algorithm [61]. For error compensation, they have used a fuzzy hybrid knowledge inference mechanism (FHIIM) [62]. They have created rules based on the size, color, and location based on the distance between the headlights of a vehicle using fuzzy logic.

C. Vision-based Approaches

An important indication of vehicle detection is the vision-based approach. Therefore, in-vehicle detection, most researchers prefer to use vision-based approaches.

S. Padmavathi, C. R. Naveen, and V. Ahalya Kumari [63] implemented an algorithm to detect headlights based on spatial adjacency, which is less effective due to the combination of two-wheeler headlights with four-wheeler headlights. The headlights have been identified in this work depending on elliptic bright spots. Their proposed algorithm segregates 4-wheeler headlights from 2-wheeler headlights. The dimension of the headlamp changes depending on the remoteness of the cameras. Depending on the viewpoint of the vehicle's insight, they provided the appropriate scale factor. The headlights near each other in a single blob area were recognized and counted accurately. They claimed that the precision of counting increased to 98%. Fig. 11 displays the flow diagram of the proposed methodology.

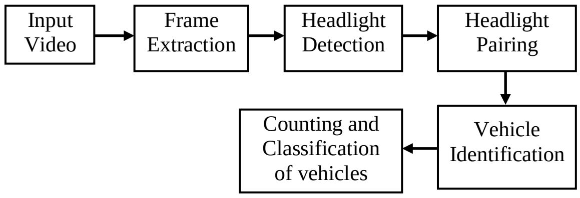

Fig. 11. Architecture of the suggested method of S. Padmavathi, C. R. Naveen, and V. Ahalya Kumari [63]

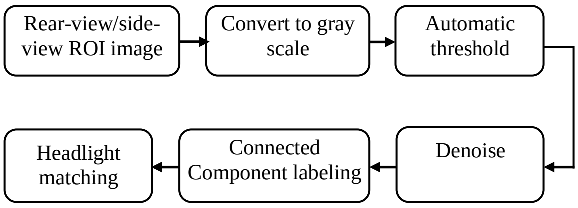

Fig. 12. Headlight detection method of X. Z. Chen, K. K. Liao, Y. L. Chen, C. W. Yu, and C. Wang [64]

X. Z. Chen, K. K. Liao, Y. L. Chen, C. W. Yu, and C. Wang [64] suggested a vision-based vehicle detection technique at night that is done by an automated multilevel thresholding process, de-noise, connected component labeling [56], [59], [60], [65] headlight matching method, and headlight tracking and classification. Their methodology determines the locations of the headlight and the vehicle and classifies vehicles and decides which type of vehicle it is. They claim that the accuracy from the side-view and rear-view is higher than 90%. Their proposed method based on headlight detection is shown in Fig. 12 and the Headlight matching method is shown in Fig. 13.

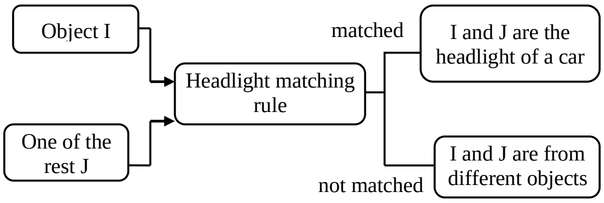

Fig. 13. Headlight matching method of X. Z. Chen, K. K. Liao, Y. L. Chen, C. W. Yu, and C. Wang [64]

The system for dynamically adjusting and identifying headlights predicated on data from a thermal camera has been proposed by Shixiao L., Pengfey B., Yuanfeng Q [5]. Thermal image improvement and multi-sequence image feature fusion have been utilized to dynamically adapt for object extraction and YOLOv3 with a filter has been used to identify objects effectively (YOLOv3-Filter). The filter can differentiate between elevated or low beam features. The precision of this technique is 94.2 %, and according to the results, it is 78.7 % in real-time at 9 fps. For dynamic adjustment and distinguishing approaches, a single-shot detector (SSD) network has also been utilized with superior results in tiny object identification. Because of this SSD network, the accuracy has been increased by 8.2%.

Yuta S., Kosuke N., Gosuke O. [66] suggested a system for detecting vehicles using monocular camera images taken while driving at night. Bright spots have been identified using effective binarization based on vehicle light characteristics such as brightness and color. As a result, the bright spots have been identified using Random Forest, a machine learning technique for multiclass classification. In the suggested method, the characteristics of bright spots that have been associated with vehicles were effectively used in vehicle detection.

S. Parvin, L. J. Rozario, and E. Islam [67] introduced a novel vision-based method for detecting and tracking vehicles based on headlight and taillight features. Two adaptable fixed Regions of Interest (ROI) have been employed, which could adjust to various image and video resolutions. They have indicated that two ROIs might well be carried out simultaneously in an image and video sequence for the detection of incoming and outgoing vehicles at night. The components of red and white have been extracted using the double threshold technology for vehicle detection, and the Euclidean distance method and centroid tracking algorithm have been applied for vehicle tracking. They have obtained around 97.22 % and 0.01s per frame of average precision and processing time.

D. Machine Learning-based Approaches

Y. Li, Norman H., and Sharath P. [68] suggested the use of an automated machine-learning headlamp controlling system to autonomously regulate the beam condition of a vehicle while the nighttime driving focused on detection from videos by an inbound/overbound/leading traffic along with urban areas. In this research, the researchers used machine-based learning approaches, such as support - vector machine (SVM) [69] and AdaBoost [70], [71], [72]. They claimed that their proposed system has widely been tried both online and offline. Fig. 14 shows the architecture of the headlight control system.

A. Bell *et al.* proposed an approach for the real-time identification of nighttime vehicles in [73] that assesses complex light patterns in able to track vehicles on the frame. For this purpose, a new machine learning system has been developed depending on a grid of foveal classifiers. The same global image descriptor has been processed by each classifier in the grid. However, each of them is trained to estimate a varied performance based on the classifier position in the grid and the vehicle location. They experimented with point-based annotation in a newly built nightly dataset to show that the presented technique is accurate.

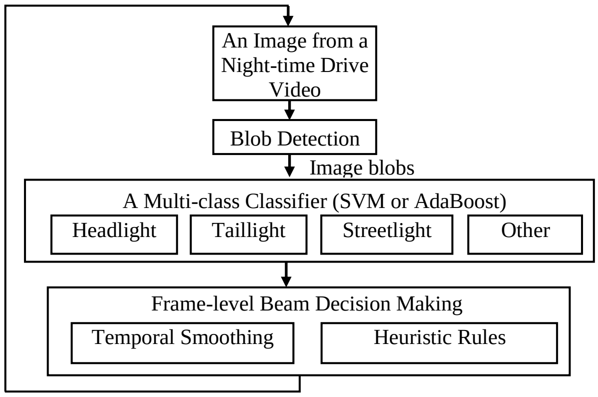

Fig. 14. The overall three-level architecture of the suggested intelligent headlight control (IHC) system Y. Li, Norman H., and Sharath P. [68]

Pham, T.A., Yoo M. [74] utilized night occluded vehicle lights for vehicle detection and tracking system. The first step has been to extract the bright blobs (vehicle lights) in the recorded image. A machine-based learning technique is suggested to determine if the light lamps are headlights or rear lights. According to their results, headlights handle occlusion 94.64% of the time. They reported that the performance of their proposed method is successful, but their work has some bugs. 1) The suggested technique does well in partially vehicle occlusion but cannot achieve cumulative vehicle occlusion; 1) Motorbikes are not covered in the research.

Shang J. *et al.* [75] suggested a multi-scale local saliency detection-based region-of-interest (ROI) segmentation technique for vehicle headlight detection. The approach preserves dim or small-sized objects while retaining the object's original shape to the maximum extent possible. The pyramid histogram of oriented gradient (PHOG) features has been subsequently calculated and used to train the SVM classifier. Finally, the extracted bright blocks are classified using the SVM classifier that has been pre-trained. The experimental findings and quantitative assessments in diverse situations show that their suggested technique can outperform prior methods.

E. Deep Learning-based Approaches

Ligayo M. A. D., Costa M. T., Tejada R. R., Lacatan L. L., Cunanan C. [76] presented a method for detecting and counting on-road vehicles using vehicle headlight identification. The purpose of this research has been to identify the headlights of all vehicles using YOLOv3 and CNN architecture. They have trained the AI to recognize headlights in various circumstances so that the system can detect vehicles with headlights both during the day and night. They claimed that their proposed system's accuracy in recognizing vehicle headlights is 86.7219 %.

The image-based vehicle identification system of Chen J. c., Chen Y. F., Chuang C. H. [77] operates both day and night. A regional neural convolution (RCNN) network is utilized to identify the vehicle's location in a video during the day for vehicle detection. The movement of the vehicle is indicated by the headlights at night for vehicle detection. They asserted that their proposed technique could provide greater accuracy and recall. They obtained an accuracy of around 95.1 % and a recall rate of almost 97%.

Piotr B. and Rafal D. [18] implemented a system for increasing the precision of the classification of vehicles. The procedure involves evaluating the properties of the blob and the positions of the detections. The authors suggested a new feature to describe binary blob shape (BBS). The BBS consists of eight values representing the binary blob's shape. Their proposed method is based on convolutional neural networks (CNNs). Two CNN classifiers have been used, and it contains three convolutional layers. They stated the mean precision in this work reached more than 93%, and the BBS function considerably enhanced the classification accuracy by around 1%.

F. Other Approaches

I. Sina *et al.* [78] developed a method for recognizing vehicles based on headlights and measuring vehicle speed in low-light conditions. To retrieve information from CCTV, a few procedures must be taken. First, the vehicles are identified using the normalized cross-correlation [79], [80] technique, and the centroid-area-difference. Following that, the vehicle's motions are tracked using the headlight, and the vehicle's count and speed are estimated using the pin-hole and Euclidean distance [81] methods. They reported that the normalized cross-correlation technique outperforms the area-centroid difference method in terms of accuracy. In addition, the pin-hole model outperforms Euclidean distance in determining vehicle speed. Their proposed process flow is shown in Fig. 15.

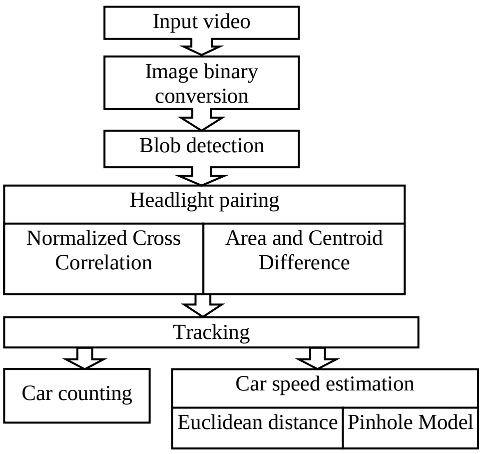

Fig. 15. Process flow for vehicle counting and speed assessment of I. Sina *et al.* [78]

Darko J. and Sven L. C. [82] have suggested a system of vehicles that can identify and track headlights in rural and urban areas. A tracking system depends on the Joint Probability Data Association Filter (JPDAF), which efficiently integrates object detections with existing tracks. According to them, their proposed approach detects vehicle headlights with high precision. Their proposed technique is displayed in Fig. 16, and Fig. 17 presents their tracking approach.

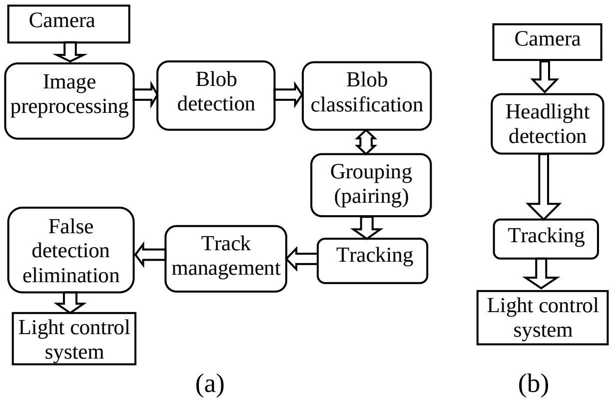

Fig. 16. Approaches for vehicle light detection and tracking. (a) The block diagram of a usually used technique. (b) The block diagram of the suggested abridged technique, which comprises of only two stages of Darko J. and Sven L.C. [82]

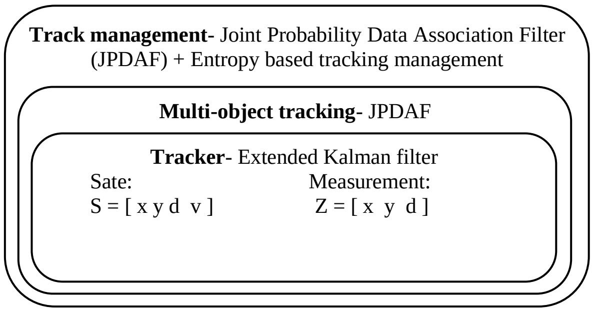

Fig. 17. The structure of the tracking algorithm. An object is tracked by means of the extended Kalman filter owing to non-linearity of the motion model. Several object tracking is accomplished by JPDAF of Darko J. and Sven L.C. [82]

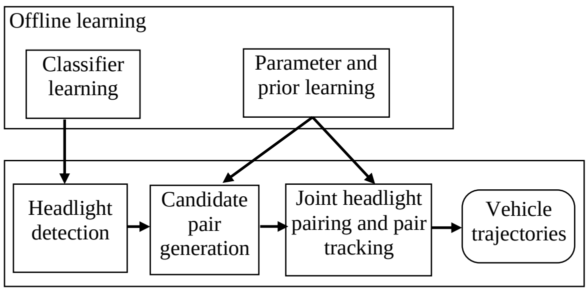

Fig. 18. Structure of weighted SP-based nighttime vehicle tracking system of Qi Zou H. Ling, Y. Pang, Y. Huang, and M. Tian [83]

In [83], Q. Zou, H. Ling, Y. Pang, Y. Huang, and M. Tian presented a nighttime traffic monitoring system that combines headlight pairing and pair tracking in a single weighted SP (set packing) structure. The disjoint tracking specifications and the no-sharing-headlight pairing criteria are represented in the edges of a graph that contains potential pair track hypotheses as nodes. When a network resolves a weighted SP issue, vehicle trajectories are generated that are simpler to correlate with the temporal sense and hence provide good quality trajectories. Fig. 18 illustrates the suggested context for the nighttime vehicle tracking system based on weighted SP.

IV. Nighttime Vehicle Headlights Intensity Control

This study focuses on all technologies and techniques designed to control the intensity of vehicle headlights to reduce the discomfort of unexpected glare during the night: using an LDR (light-dependent resistor) [84], a fuzzy logic sensor, wireless sensor network [85], an IR (infrared radiation) transmitter-receiver, and a PWM [86]. These technologies, however, have not been utilized in a realistic context and are restricted to research prototypes. The technology of headlight intensity control and its likely limitations [87] are briefly explored.

- *Light Dependent Resistor:* The resistance value of an LDR changes with the intensity of the incident light.
  Limitation: It is not considered the distance of the next vehicle.
- *Fuzzy logic-based intensity control:* The fuzzy sensor collects the data and sends it to the microcontroller to convert it to environmental illumination intensity.
  Limitation: Due to the dimension problem, it is difficult in practice to set a rule basis with more than three components.
- *Wireless Sensor Network:* This system provides an autonomous gateway connecting the wired database and sensor network wirelessly.
  Limitation: Interference with other frequencies using wireless media is always possible, which makes it challenging to effectively send data in an appropriate timeframe.
- *IR transmitter-receiver:* Since the human visual system cannot see IR radiation, it is the favored radiation used in the electrical spectrum of wireless communication.
  Limitation: The range of transmissions is somewhat less (within 10 meters). This results in reductions in performance if the remoteness between the transmitter and the recipient is more than the capacity of the IR unit.
- *Pulse Width Modulation:* PWM is a technique for controlling simple circuits in conjunction with a microcontroller.
  Limitation: This technology requires the utilization of low-speed and high-speed semiconductor devices that are both expensive.

In addition, the introduction of the Internet of Things (IoT) has provided a new route for addressing this problem. This technology opens new opportunities for sharing massive amounts of data by utilizing cloud databases. IoT may be used to send headlight intensity information to other vehicles in a specific region. These data are sent to both drivers in a defined area to change their beam intensity correspondingly. If the driver does not alter the intensity at a specified distance between the two vehicles, the low beam will automatically be triggered. Although this is a basic approach, it provides a path for working on this challenge through the deployment of IoT.

Various scholars and manufacturers researched and developed numerous headlight technologies in vehicles. They are discussed briefly.

Rajas S. P., Rajiv S., Samruddhi N., A. E. Thomas, and Mr. Tushar C. [16] introduced a method for implementing smart LED headlights based on image processing. A novel technique for identifying vehicles at night based on the vehicle's lights has been developed to adjust the brightness of a multi-beam LED headlight. Other light sources, such as lampposts, pose a significant problem. As a result, a photodiode has been used to detect the vehicle's incoming light. This approach can be improved in real-time traffic conditions in the future. The flow diagram of their suggested prototype is illustrated in Fig. 19.

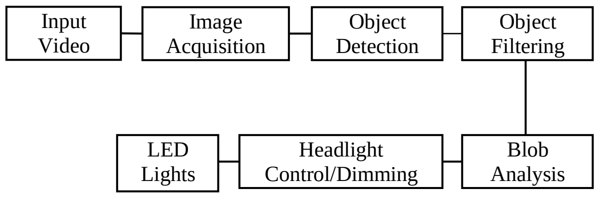

Fig. 19. Block diagram of Rajas S. P. Priyanka, D. Rajiv S., Samruddhi N., A. E. Thomas, and Mr. Tushar C. [16]

Priyanka D. and Mr. Nanaware J. D. [88] suggested a system based on AFS (Adaptive Front-lighting System) [89], [90], [91] technology that assists in improving the driver's visibility at night. AFS has utilized a sensor to sense information about the corner in advance and send it to the servo motor to adjust headlights to get the proper lighting beam for the corner. When approaching a corner, it may be possible to avoid the "blind spot" formed by the fixed lighting zone, therefore improving driving safety. This AFS system could be further developed in the future in the face of complex road conditions. The suggested prototype of the Adaptive Front light system is displayed in Fig. 20.

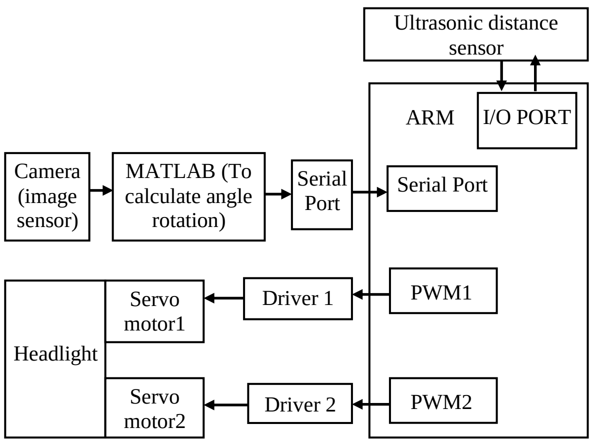

Fig. 20. Block Diagram of proposed design of Priyanka D. and Mr. Nanaware J. D. [88]

Devashree C., Manasi J., Sanjyot K., and Seema D. [6] and Muralikrishnan R. [14] introduced an adaptive headlight brightness control system based on LDR (Light Dependent Resistor) that controls the intensity of the headlamp. With the intensity of the incoming light, the resistance value of LDR fluctuates. Transistors, such as BJTs and MOSFETs, are triggered devices used to regulate gate current and the realization of a potential divider made out of resistors. A switching device (relay) with two contacts is utilized. In general, an open contact is related to the vehicle's low-intensity LED, and a closed contact is associated with the vehicle's high-intensity LED.

Aslam M. R., Bala K. T., Seetha R. N., Shankar M., and Swathi R. [92] proposed a device to minimize the issue of brief sightlessness that would sense the strength of the headlight in an analog form from the oncoming vehicle that would be transmitted to the analog to digital converter (ADC) to change the analog signal to digital signals. ADC will then send those digital signals to the microcontroller, where the strength level of the threshold is set. Two relay circuits have been used, one to switch to a high beam, and another to switch to a low beam. The high beam light will go to a low beam when the relay 2 circuit receives the signal. Their proposed scheme is shown in Fig. 21.

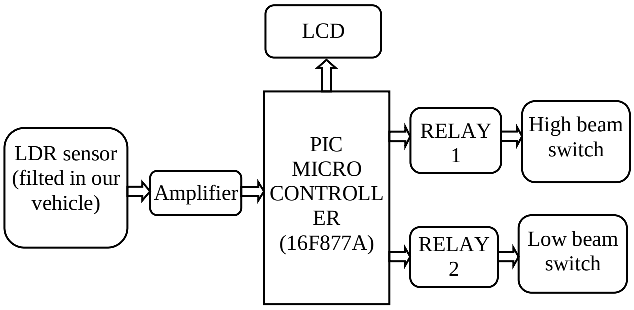

Fig. 21. Block diagram of Aslam M. R., Bala K. T., Seetha R. N., Shankar M., and Swathi R. [92]

Arpita K., Akhila M. J., Avi K. R. [15] developed a prototype of an automated headlamp intensity control system with the hopes of reducing glare and dimming the brightness. This prototype reduces the requirement for the driver to use the manual switch, which is not usually used. They argued that their suggested system could be utilized by two vehicles where the vehicle's high beam may be regulated with the help of other vehicles coming in opposite directions and vice versa, utilizing the LDR sensor and Zigbee connectivity to a higher extent to avert accidents.

V. Image and Sensor-based Approaches

The sensor is a photo-sensitive device. This approach captured images from the camera, and the sensor senses vehicles at night and estimates the position of other vehicles based on light intensity [4], [13], [18]. Centered on headlights, there are several methods available for detecting and identifying vehicles at night. These are discussed briefly.

Antonio L. *et al.* [93] introduced a new technique for real-time vehicle identification at night based on an intelligent headlight controller. They utilized a new image sensor with a clear-red pattern. They suggested a new classification architecture and an analysis of spatial consistency, which may achieve relatively high detection rates with very few false positives. Using this method, the intelligent headlight controller may respond to targets that are visible vehicle lights from a single frame. The efficiency of vehicle identification can be increased in the future by implementing a new function. Fig. 22 shows their proposed method.

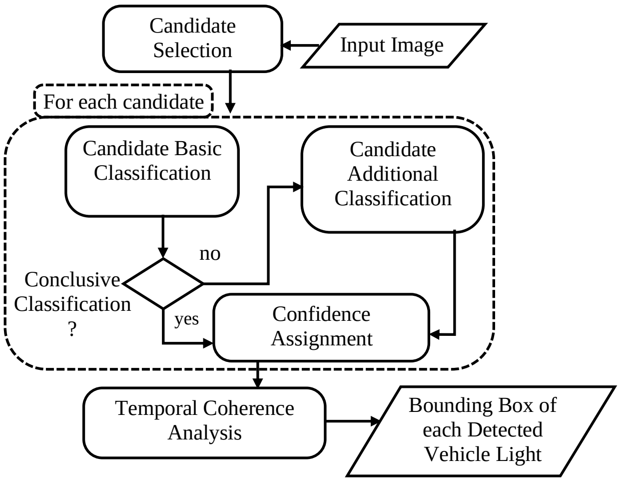

Fig. 22. Proposed vehicle detection method for nighttime images of Antonio L. *et al.* [93]

Pushkar S. and S. B. Dhonde [13] devised a way to detect and choose an appropriate vehicle beam that is suited for temporary blindness reduction. Researchers utilized two ways to alleviate headlight glare and temporary blindness. The image sequence is then analyzed for detecting the vehicle's existence [4], [18]. Another option for dealing with temporary blindness is to use a light intensity sensor. They also revealed that their suggested method effectively recognizes vehicles, with a detection rate of 94.84 %. Fig. 23 shows their proposed approach for vehicle detection.

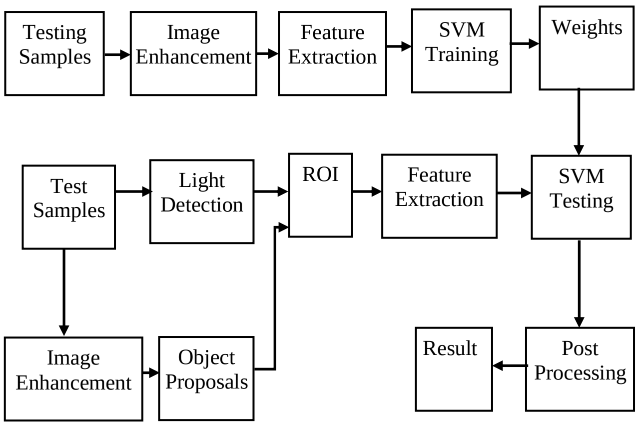

Fig. 23. Block diagram for nighttime vehicle detection of Pushkar S. and S. B. Dhonde [13]

Huang H. W., Lee C. R., Lin H. P. [8] have been designed a vehicle identification system centered on an RCCC image sensor to identify and track vehicle highlights in the night. The RCCC image sensor [94] enhances the red signal sensitivity, and in relatively low circumstances, removes additional noise than the Standard Bayer sensor. Spatial analysis is carried out at the detection stage for the extraction of local characteristics and the selection of the candidate area of the image. The forefront and background components have been segregated and three major assessments have been used to remove any identified bogus objects, such as headlight reflections on the road surface. Fig. 24 shows their proposed system architecture.

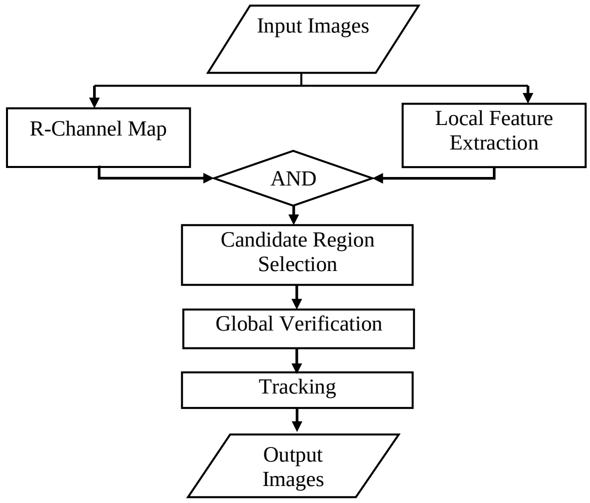

Fig. 24. System architecture of H.W. Huang, C. R. Lee, and H. P. Lin [8]

VI. Common Approach for Vehicle Detection based on Headlights

Nighttime vehicle detection is a magnificent research area. The studies of nighttime vehicle detection have been discussed by several scholars. Vehicle tracking and driver aid systems [3], [4], [7], [10], [13] have been utilized widely in the area of nighttime vehicle detection. Based on their headlights, there are plenty of techniques available to identify and recognize vehicles at nighttime. We have adopted a common approach of nighttime vehicle detection based on headlights, in line with the different methods and techniques suggested by the various researchers mentioned above. The proposed common approach of nighttime vehicle detection using headlight feature which consists of five stages. Firstly, input images are taken from the camera by the vehicle detection system. Binarization and noise removal on the input image is then done in the preprocessing stage. Thereafter, the ROI (Region of Interest) is applied to capture the image area mentioned. And finally, to detect vehicles, apply the required algorithm to the headlight detection block. Fig. 25 shows the block diagram of the common methodology for nighttime vehicle detection based on the headlight.

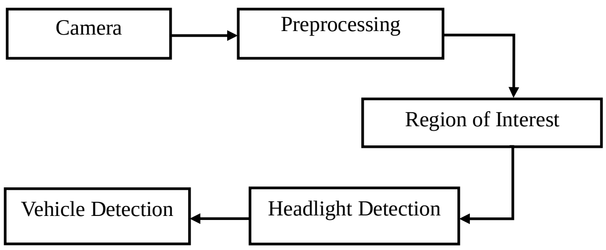

Fig. 25. Common methodology for nighttime vehicle detection based on headlight.

The proposed algorithms, accuracy, advantages, drawbacks, and future directions of nighttime vehicle detection analysis using headlight features obtained from various researchers are presented in the arrangement of a summary in Table 2, and Fig. 26 shows the classification of the techniques for nighttime vehicle detection and headlight intensity control.

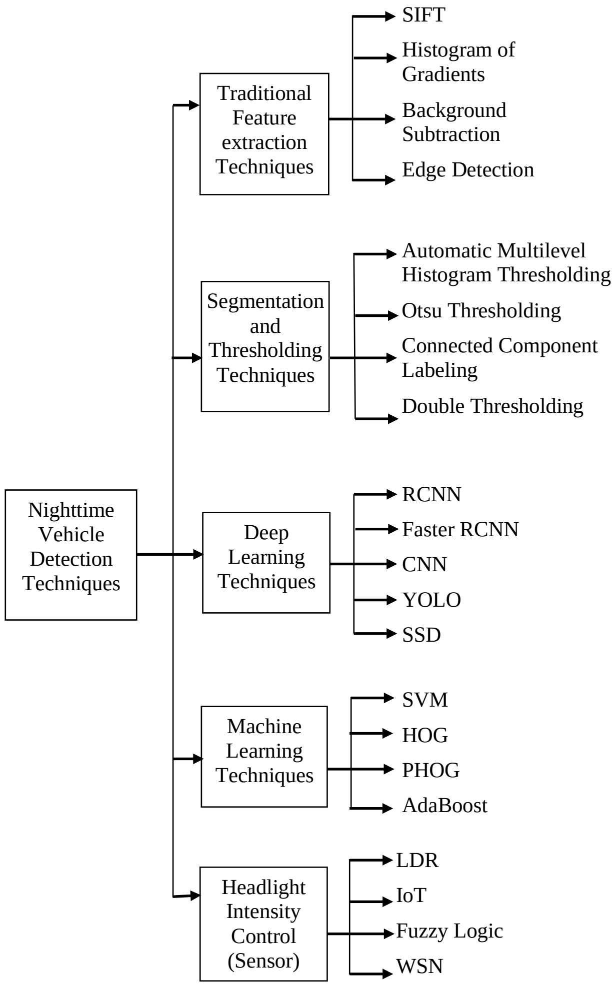

Fig. 26. Classification of the techniques for nighttime vehicle identification and headlight intensity control.

VII. Conclusion

A comprehensive study of the identification of nighttime vehicles based on headlights has been presented in this review paper. It centers on some of these areas: vehicle detection, tracking, and classification with external disturbances and light appearance. Many researchers have been continuing to work on an extensive area of detection of night vehicles and control of lighting intensity. Nighttime vehicle identification is a highly challenging procedure according to illumination circumstances. This paper provides significant details about how the proposed systems detect, segment, and track vehicles using sensor-based methods, image processing methods, and analytical tools. More specifically, this research concentrates on nighttime vehicle detection systems based on headlights and provides a comprehensive understanding of the problems as well as solutions. Based on the study efforts in this field throughout the world, it is expected to remain one of the top research fields in the future. Commercial manufacturers, government organizations, and universities are anticipated to collaborate to achieve considerable advances in this field in the coming years.

TABLE II
OVERVIEW OF THE NIGHTTIME VEHICLE DETECTION STUDIES USING HEADLIGHTS.

First Author & Year	Algorithms	Accuracy (%)	Advantages	Limitations	Future Directions
H. Fleyeh (2012) [11]	SVM classifier, pairing algorithm, multi-object tracking algorithm	97.9%	Robust system and detects all vehicles with a pair light.	The proposed system cannot detect vehicles with a single light.	Extended Kalman filter can be employed for tracking, other features can be used which requires less processing time.
Yingfeng C. (2016) [12]	Visual saliency and Deep learning	92.3%	Proposed system is fast and accurately with less processing time.	A few bright blocks are misidentified as vehicles.	To work with detection rate and false detection.
C. H. Hsia (2017) [27]	Image processing techniques, Connected Component Labeling	97.67%	Provides real-time management	..……	To work with more detection rate.
D. Xiaodong (2019) [28]	Hough Transform algorithm	98.46%	Provides less processing time than other daytime vehicle detection system and low false alarm.	The detection rate is not excellent if the detected action looks round and circular.	………..
Piotr B. (2019) [18]	Convolutional Neural Networks (CNN), HOG feature, Intensity and Color feature	93.63%	Gave significant improvement in classification accuracy of about 1 %.	Training process takes more time.	The new feature can be added, new data augmentation can be applied.
Y. L. Chen (2011) [10]	Bright-object segmentation, Automatic multilevel histogram thresholding, Clustering techniques	Urban road: 98.79% Highway: 97.73%	In different night conditions the proposed method is efficient and useful.	The proposed method fails to perform effectively on vehicle detection and does not identify single light in crowded situations.	The classification method can be enhanced and extended by machine learning techniques such as SVM.
M. Taha (2014) [7]	Automatic thresholding, Rule-based component analysis, tracking algorithm	Urban road: 96.27% Highway: 95.76%	The suggested approach is viable and very productive.	Unable to identify low-visibility vehicles, parked vehicles, and single-light vehicles.	To attain more accuracy and tracking rates.
Jacob V. P. (2015) [3]	Automatic thresholding, clustering techniques, pairing algorithm	88%	The suggested system is very useful for vehicle detection and classification.	The proposed system can only detect vehicles with paired lights, no single light.	To improve and extend with some machine learning techniques and improve accuracy.
Shixiao L. (2020) [5]	YOLOv3, single-shot detector (SSD)	94.2%	Provides good performance in small-object detection.	The unpredictable size of the vehicles causes some mistakes in this technique.	More accuracy can be achieved in the future.
V. H. Pham (2016) [52]	K-means clustering-based segmentation, Kalman filter	98%	Provides real-time performance.	The proposed system can only detect vehicles with paired lights.	To work with machine learning techniques
T. A. Vu (2017) [24]	Segmentation techniques, Tracking algorithm, Pairing algorithm	81.19%	Provides real-time performance.	Some false detection and miss detection are caused by headlight reflection on the road.	To improve and extend with classification techniques.

S. Padmavathi (2016) [63]	Pairing algorithm, Vision-based congestion analysis techniques	98%	Provides real-time processing speed.	Fog lights are identified as completely different directions in current four wheels, which impair precision.	In the future, actual distance can be computed between the headlamps and fog lamps.
X. Z. Chen (2018) [64]	Automatic multilevel thresholding, matching algorithm, tracking algorithm, classification techniques	Higher than 90%	Proposed system is fast enough to use as real-time system.	when the surrounding circumstances are too complicated, the proposed system cannot detect vehicles correctly.	Object recognition and path prediction can be extended improved.
Y. Li (2011) [68]	support vector machine (SVM) and AdaBoost	Higher than 90%	Provides real-time performance.	The proposed technology does not detect the vehicle at 400 m distance and generates false positive by road reflectors and street signs on curved highways.	More accuracy can be achieved in the future.
Pham, T. A. (2020) [74]	Haar features, Lab color feature, multiclass Adaboost classifier	94.64%	The technique is extremely successful in its performance.	The proposed method cannot solve complete vehicle occlusion and cannot detect single light vehicle. False detection occurs in heavy traffic.	In future, the algorithm may be used in daytime conditions and the identification and tracking of motorcycles can be incorporated into the current system.
I. Sina (2013) [78]	Normalized cross-correlation method, Centroid area difference, Pinhole and Euclidean distance methods	Higher than 80%	In smartphone-based system, every second the actual vehicle velocity data is sent to the server.	The proposed system cannot detect single light vehicles such as motorcycle.	In the future, more accuracy can be achieved.
Darko J. (2014) [82]	Joint Probability Data Association Filter (JPDAF)	Rural: 97% Urban: 87%	Simplicity in architecture compared to the usual approach of identification and tracking.	Certain false positives, such as streetlights, cannot be prevented.	The method may be further expanded to follow the rear light of the vehicle. The incorporation of the data about the location and velocity of the objects might reduce false positives.
Q. Zou (2017) [83]	Weighted Set Packing model, AdaBoost, Haar detector, Pruning strategies	90.1%	Provides excellent performance by the suggested method.	In lengthy occlusions, vehicles with random headlights and crossings, the proposed technique remains problematic.	In the future, this system can be deal with long-term occlusion and can be optimized the algorithm by GPU parallel programming. Vehicle classification can be added.
S. Parvin (2021) [67]	Double Thresholding, Euclidean Distance, Centroid Tracking Algorithm	97.22%	The double lights and single lights can be detected and tracked by the suggested method.	In complicated roads and foggy weather scenarios, vehicles are not correctly identified.	This work can be extended by the vehicle's brake lights. Discrete graphics may be used in the future to improve detection.

Chen J. C. (2019) [77]	Region-based convolutional neural networks (RCNN)	95.1%	The suggested technique of overtaking vehicle detection is employed both during the day and at night.	The overall detection has an impact on bad weather or light pollution, like wet day, signpost light, and illumination.	The difficulties will be the reference for future study.
H. W. Huang (2017) [8]	RCCC sensor, spatiotemporal analysis, global verifications	92.55%	Provides less computation time and a stable tracking result.	In poor image resolution, the proposed system detects false detection.	More accuracy can be achieved.
Ligayo M. A. D. (2021) [76]	YOLOv3, CNN	86.7219%	The proposed system can detect headlights during both day and at night.	Other vehicles captured by the camera are not detected.	The suggested technology may be incorporated into CCTV cameras to estimate vehicle volume and monitor traffic and the accuracy can be increased by added additional datasets.
Pushkar S. (2017) [13]	SVM classifier, Image enhancement techniques, Feature extraction techniques, light intensity sensor	94.84%	The proposed system is very robust and effective.	The proposed algorithm detects many false positives.	False positives, the detection rate may be increased in the future, and other applications can be integrated (e.g., traffic monitoring, adaptive headlight beam control etc.).
Antonio L. (2008) [93]	Thresholding, Connected Component Analysis, CCCR sensor	90%	The proposed method takes less computation time.	The performance for distant vehicle lights is somewhat lower.	The future work will concentrate on increasing performance of the classification using new features.

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