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Vehicle Detection using Computer Vision and Thermal Imaging

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Abstract-The world is suffering a population crisis, and because of this, the infrastructure and resources already in place are unable to handle the increased demand. With technological advancements, the automotive industry is flooding the market with more and more cars each year. They are putting in a lot of effort to ensure that vehicles are available at a price the average person can afford. There has been a tremendous effort to improve vehicle availability, but there need to be more infrastructure improvements to ensure smooth operation. We still rely on humans and their manual labour to manage the enormous traffic volume. Using technology to upgrade the current infrastructure and improve the situation would be a better approach. So, in this study, we focused on studying various systems that have emerged over time for the purpose of vehicle detection. Most of the existing technologies needed some improvement. The paper proposes a hybrid vehicle detection system blending thermal cameras and computer vision to overcome the oddities of existing technologies. This proposed system will have high efficiency and accuracy in detecting vehicles in bad weather and poor lighting conditions.

Keywords: ***Video image processing, microwave radar, infrared, laser, magnetometer, acoustic.***

I. INTRODUCTION

Human population is increasing at a rate which is making it hard for current systems and methodologies to fulfill their needs. India has become the 5th-biggest automobile producer in the world. 4,266,062 units were estimated to be required for the Indian automobile market in 2019. In the time period from 2020 to 2027, the market is anticipated to develop at a CAGR of 11.3%. [25] The nation's growing population, increased disposable income, and the simplicity of obtaining financing all support the car industry. Moreover, it is anticipated to see increased demand for vehicles for commercial use due to the expanding logistics and passenger transportation sectors. According to IIM and the Transport Corporation of India, the volume of vehicles in India is growing annually at a rate of 10.76%, but the rate for roads is far behind [17]. This will cause a saturation condition as the available road capacity will not be enough to meet the demand. India loses a staggering $21.3 billion each year. The study jointly conducted by the Transport Corporation of India and IIM Kolkata estimates that India annually loses around 6.6 billion dollars because of the delays caused by traffic and around 14.7 billion dollars because of the extra fuel consumption [7][19]. The average speed and the average mileage of cars on the road have decreased. With an average speed of 58 km/h, India got the 127th ranking among 162 countries for speed of road transport by the International Monetary Fund (IMF) in their working paper published in June 2022. Due to this escalating population the amount of traffic on the roads is also increasing. Various technologies have emerged with time all of which tried to manage the problem of traffic with better efficiency. Technologies like inductive loop, infrared, microwave radar, magnetometer, acoustic technology, video & image processing are some of the technologies which are currently used, but all of these technologies have some shortcomings. This leaves scope for further research on this problem. We are proposing a vehicle detection system which will be more accurate and efficient in detecting vehicles in bad weather and poor lighting conditions. For vehicle detection and monitoring, we used a thermal camera and computer vision for detection. These two technologies provide more effective, reliable, and accurate results. We used

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these technologies in our proposed system because they fulfill each other's limitations.

The organisation of paper is done in this manner: Insection 2, various technologies for traffic monitoring have been discussed and compared. In section 3 a system is proposed. Finally, in Section 4, the study's conclusion and the scope for future research are presented.

II. Review of Literature

The two categories of road traffic detectors are: - [15]

- Embedded detectors: A roadway's surface may have sensors in it or under it that make up an embedded detection system.
- Non-intrusive detectors: The term "above ground detectors" is also used to describe non- intrusive detectors. They are attached to a structure that is elevated above the surface.

A. Existing Technologies

1) Inductive Loop (IL)

When installed into or beneath the surface of a roadway, an inductive loop made of wire coils that typically have a square, circular, or rectangular shape serves as a metal detector by measuring the variation in the electromagnetic field caused by an object passing over them. IL are implemented in conjunction with axle sensors as presence detectors of objects to get classification information such as spread and length data.

Inductive loop are divided into 4 parts :

1) Loop of wire beneath road surface.
2) From the wire loop, an input cable connects to a pull box.
3) The input wire at the pull box is connected to the controller by an input cable.
4) The controller cabinet's electronic component [16].

In [18], three methods for utilising IL to identify automobiles are discussed.

1) Single inductive loop system: Variables observed by this method are: volume, the magnetic signature of the automobile that allows the automobile's classification, occupancy, and time intervals between successive auto- mobiles. The more advanced evaluation of the magnetic signature enables counting of the amount of axles, their corresponding distances, and automobile dimension in addition to estimating specific speed of the automobile and trailer recognition.

2) Multiple inductive loop system: This method observes variables like: volume, occupancy, speed, individual vehicle length, trailer presence, time intervals between successive automobiles, and automobile class according to the vehicle length and presence of a trailer.

3) Inductive loop with piezo sensors system: This is most sophisticated system and has two piezoelectric axle sensors and one inductive loop sensor. This system observes the following variables: volume, occupancy, speed, length, number of axles, spacing between individual axles, magnetic signature, presence of an automobile trailer, and duration among subsequent automobiles.

2) Laser

The method suggested demonstrate the dependability of their approach as it operates in heavy, congested traffic on highway, attaining over 98% efficiency for detecting vehicles and categorization. Due to the employment of a mono laser, anomalies happen whenever big trucks pass underneath the data acquisition device. Depending on how these vehicles behave, a simulation has been developed to predict the ideal laser location in order to decrease the occlusion impact &, hence, improve the likelihood of identifying a PTW. They applied sequential optical detection process, automobile laser hits, and spatial-temporal 3D modelling. Main working: the process of creating statistical measurements of vehicles passing below the LIDAR (Light Detection and Ranging), followed by the process of characterizing vehicles via ML algorithms, and furthermore, when assessing PTW traffic.[28] Powered two-wheelers, passenger cars, vans, lorries, or buses are all the 5 types into which the categorisation has been divided. A laser scanning sensor is employed as the detecting system. They subjected to parametric (T-Test, ANOVA) and non-parametric tests in order to identify the characteristics that do not give extra details that provides the chance for combining it with various area detection-capable sensors concept of vehicles, fast recognition and identification precision characterization MAIN: The embedded system, sometimes called the control unit (CU), software categorization programme, and sensors actually make up the detecting. Traffic

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beam's pole has the sensor mounted. The equipment and connectivity component are part of the CU. The computerised categorization software comes last. A proprietary method developed by the sensor manufacturer is used to communicate by RS422 between both sensor & CU[31].

3) Infrared

Vehicles, surfaces of the road, and other things are all capable of emitting energy. This energy can be detected by infrared sensors. The IR sensor collects energy, which is focused onto a substance that is sensitive to infrared light via an optical system, which subsequently transforms that energy into electric signals. [17] Infrared sensors, both active and passive, are produced for use in applications that monitor traffic flow. In active infrared sensors, low power infrared radiation delivered by laser diodes illuminates detection zones. No energy is transmitted by passive sensors. Instead, they sense energy coming from some sources. These sources can be energy released by moving things in their area of view, such as cars and road surfaces. Energy that enters the sensor aperture after being reflected by nearby objects like cars or roads [16] The IR sensing technology is a great option for controlling the traffic signals, sensing the presence of pedestrian and traffic information transmission.

4) Microwave Radar

A system which uses the technology of microwave is another great option for this purpose. It has great precision, a longer range, and is susceptible to light or weather. Microwave radar detectors come in two different varieties. The first broadcasts a waveform with well-known properties, also known as (FMCW) which stands for frequency-modulated continuous wave. By calculating the distance between the sensor and the target vehicle, it can identify both static vehicles and vehicles which are moving. The time taken by the car to move from one marker to another marker which are at some distance from sensor which is known is utilized to compute the speed of the car. On dividing the gap between two markers by the amount of time taken by that vehicle for covering that distance we can get the vehicle's speed. [22] The second kind of microwave radar sensor continuously broadcasts electromagnetic waves which falls under K band (24.125 GHz)for measuring the speed of moving objects in its range. It also provides a double-channel (I/Q) signal which has frequency less than ca. 8KHz, which is in proportion with the velocity of the object [6]. This type of system is based on the Doppler effect. Unlike most radar scanners, which find the speed of a moving vehicle within a small zone, the Doppler sensor allows detection of movement of a vehicle within a longer segment of the road. Electromagnetic waves of constant frequency are transmitted from the sensor. Some moving object reflect these waves, which are then sensed by the sensor. Now, as the Doppler effect suggests, there will be a change in the waves transmitted and the waves received. A different signal is produced using an I/Q mixer, which makes the detection of the vehicle's direction of motion possible. [21][4]

5) Magnetometer

Huge quantities of metallic elements (such as cobalt, steel, nickel, or iron) are used in the construction of vehicles, and this causes a modest, local disruption in the flux line of Earth's magnetic field. Different vehicle characteristics lead to diverse distortions which can be sensed using geomagnetic field components. These alterations are a vehicle's magnetic signature, which is distinctive and measurable with the use of a magnetic sensor. Sensors like FXOS8700CQ—a couple with 3-dimentional accelerometer & magnetometer are used for the identification of vehicles. Techniques for using magnetometers to detect passing automobiles were reported in [2].The most widely used systems are listed in [27].These techniques require installing the detectors beneath the roadway. A new approach for automobile detection was introduced in [26]. This approach eliminated the requirement to dig a sensor installation channel. By using magnetic fields, the scientists have also proposed an automobile recognition system that can work accurately in the disturbance caused by other heavy automobiles in different lanes. The automobiles were categorised using "magnetic length and magnetic height". A sensor network that permits the numbering and categorization of automobiles was presented in [2]. This system consists of a magnetometer, an accelerometer, a temperature sensor, a GPS module, and an IEEE 802.15.4 wireless communication interface. This technology can work efficiently in meteorological conditions like fog, snow, rain, and much more. Later in [14], "portable anisotropic magneto- resistive sensors" were applied for automobile

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detection. A microcontroller is used, that serves as the system's core for operating component. There are two phases of this method. Three "AMR sensors", an "LCD", and a" zigbee interface" connected to a "PIC" microprocessor make up the sensor portion I. Portion 2 Monitoring section: comprises of "USB to TLL", "Zigbee", and PC interface. "A silicon chip" and a substantial sheet of "piezoresistive nickel-iron" make up an "AMR" sensor. Because of the close proximity of a vehicle, this sheet's resistance changed, causing a disruption in the magnetic flux.[1] discusses a new system with creative sensor combinations. This technology was specifically created to assist multiple systems for automobile detection. There are two phases of this method. The first is based on Synapse's SNAP Connect E10 and is called an intelligent access point (iAP) . The E10 is a fully functional embedded Linux system that includes an RF module for SNAP network administration and an Internet gateway. The second one is based on Intelligent Vehicles Counting and Classification Sensor (iVCCS) nodes. Cordless networks with magnetic sensors are also used to detect automobiles [32]."SMD" and "CCD" are used together for efficient power consumption.

A Gaussian filter is used to reduce the disturbance generated by automobiles. K-means grouping is proposed to create a reference for "CCD." By using "NCC" in the middle of magnetic signals and the two sensors aligned on the road.

6) Acoustic

In [3], an acoustic sensor-based automobile detection method is introduced. Couple of mics/sensors placed along the roadside, is used by that system. The detection technique takes use of the notion that the sound from a moving automobile hits the mics at slightly periodic times. By calculating the "cross-correlation" of the mics readings, the time gap is calculated. The automobile's position matches to the "cross-correlation "system's maxima. As a result, that method makes it possible to determine the sound map, which depicts the movements of the automobile along a predetermined track. This technique's specifics are covered in [8]. The traffic prediction component of this technology is utilised to automatically identify lane locations based upon the statistical data passing by motors after initially using a cross built - in microphone for capture highway traffic sounds [20]."37" mics are arranged in a pattern. It makes it possible to measure traffic metrics for several roadways, Automobile was identified by accounting for the duration of a monitoring region's presence. A technique based on an auditory signal captured by one mic was developed and explained in [10]. This system uses "ANN and KNN classifiers". To decrease unwanted sound and to find the maxima in the studied data, a pre-processing approach was used. Automobiles are distinguished into 3 classes-heavy, medium and light vehicles.

7) Video Image processing

The used algorithms must be generally applicable, quick, and exact in order to develop an effective perception TMS [9]. First step is a summary of a few exemplary works on object identification and classification. Current frame division, shade elimination, and automobile classification techniques are given along with a variety of approaches that can be used to identify and categorise different road users, traffic videos [11]. A comprehensive framework for object identification is used for three crucial types in a single traffic sensor. Road signs, automobiles and bicycles [13]. Two systems were proposed one of which focused on image sharpening and the other system made use of blob technology and an algorithm was made for determining the priority of a lane [24].There were two key stages to the estimation of the automobile's speed. In the first stage (data gathering), a data set is created, & in the 2nd stage, a predictive model is built using this data set to forecast automobile speed from image sequences. In the first stage, this method integrates the use of the Kalman filter to forecast the trajectory of the automobile with the use of YOLO to find several automobiles. The 2nd stage estimates the automobile's speeds using valid samples as the input for various statistical & ML techniques. It is discovered that linear regression has the best-performing accuracy [23]. In the UAV video, a DL strategy for detecting automobiles is proposed. The enhanced Faster R-CNN & SSD DL systems are utilised to recognise automobiles. The data is processed by the SSD model of the proposed system following HSV transformation, & the model has potent Deep Learning capabilities that can enhance the detection result. 96.49% of automobiles were detected [30].

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B. Review in Brief

Study	Application	Source of data	Description	Finding	Shortcoming
[5]	Detection of Vehicle, classification and es- timation of speed	Inductive loop	Three methods for utilizing IL to identify automobiles are discussed.	The study examines the fundamental issues pertaining to road traffic measures	Traffic interruption was faced during installation. Road repairs cause harm to the road .
[12]	Detection ,monitoring and counting of passage of automobiles	Infrared laser sources and detectors	The suggested system combined computerized signal processing and co- relation methods with infrared laser sources and detectors.	Tests proved the ability to identify, track, and count the passage of automobile road traffic.	When visibility was less than 20 feet (6 meters), fog or snow blizzard conditions had an impact on operation.
[29]	Detection of Bicycle	Microwave radar	High detection accuracy has been demon- started in tests using a small bicycle.	Bicycles and auto- mobiles can be dis- tinguished using a straightforward study of sensor data.	Road surface installation of radar was required.
[32]	Detecting vehicle and speed detection	Cordless networks with magnetic sensors	An automobile detection algorithm in which SMD and CCD are used together and a Gaussian filter is used to reduce the disturbance generated by automobiles.	The accuracy and re- liability of proposed algorithm is tested in a favorable test envi- ronment and it was found to be around 99% for arrival and departure.	Multiple units were needed to detect the entire lane in a vehicle with the tiny detection zone.
[10]	Detecting vehicle and classifying them.	Microphones placed on road side	ANN and KNN are used for classifying automobiles.	To decrease unwanted sound and find the maxima in the studied data, a pre- processing approach is used.	Sixty-seven percent categorization accuracy was attained. Multilane traffic was not taken into account. Further exploration can take in to account effects of acceleration and gear change.
[13]	Object Detection, traffic sign, car and cyclist detection	Camera sensor	A comprehensive framework for object identification is used for three crucial types of objects in a single traffic sensor.	It was showed that proposed detector system can successfully and accurately detect various objects in traffic scenario.	The system had limited accuracy in representing complex features.
[24]	Detecting vehicle,ambulance detection,fire detection	Single camera (webcam)	Two systems were Proposed one of which focused on image sharpening and the other system made use of blob technology and an algorithm was made for determining the priority of a lane.	Experiments were performed for demonstrating the system. A single camera setup was used and a suggestion for using dedicated cameras for each lane was pitched for further research.	This system did not work efficiently in bad weather conditions like fog, rain etc.

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C. Benefits And Weakness of various sensing Technology

Technology	Benefits	Weakness
Inductive Loop	• Low maintenance regardless of circumstance. • Most reliable and accurate in terms of count- ing vehicles. • Technically sophisticated. • Insensitive to bad weather, including snow, fog, and rain. • Classification information is provided via a high frequency excitation model.	• While technology is being installed, there is traffic interruption. • It's challenging to maintain traffic on installa- tion time. • Harm by the movement of big vehicles. • Harm from road repairs. • High energy consumption.
Laser	• Civil engineer is not required for installation. • Works on the road's surface. • Easy to install. • Applications for structured traffic.	• Used only in structured traffic. • Costly. • Low visibilities decreases performance (heavy rain).
Infrared	• Detect presence and passing vehicles. • Can operate 24 hours. • Increased performance & frequency sensors. • Small in size.	• There is no detail about vehicle speed. • High sensitivity found only where cool IR detector was utilized. • Reduce performance in snow, fog, and rain.
Microwave Radar	• Small size. • Installation time causes no traffic interruption. • Repairing time will cause No traffic interrup- tion. • Vehicle speed measurements in real time. • Multi-lane functionality is provided. • Typically unaffected by bad weather .	• The CW doppler sensor is unable to identify stopped vehicles. • Tools Cost and installation cost is high.
Magnetometer	• This technology is used to Detection, pres- ence, and count of vehicles. • Placed in concrete surfaces and bridge decks as loop detectors and preventers. • Easy to install. • Insensitive to bad weather, including snow, fog, and rain.	• Commonly placed via pavement cuts or drilling. • Used in small dimensions. • Lane closure was needed for installation and maintenance. • Multiple units were needed to detect the entire lane in a vehicle with a tiny detection zone.
Acoustics	• Detect passively. • Medium cost. • Used in small dimensions. • Easy to install. • Many systems provide multi lane operation.	• Low energy consumption. • Accurate car counting may suffer from the cold.
Video Image Processing	• Easy to install. • Detect large group of vehicles. • Ability to transmit live pictures to a control room. • Detect vehicles and divide them into their categories.	• High cost. • Performance reduces in bad weather.

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III. PROPOSED SYSTEM

The system we are proposing will make use of two technologies, namely computer vision and thermal imaging. Our system will identify the vehicles on the road with both of these technologies, which will help increase the detection accuracy. This will help us solve the problems faced by previous systems.

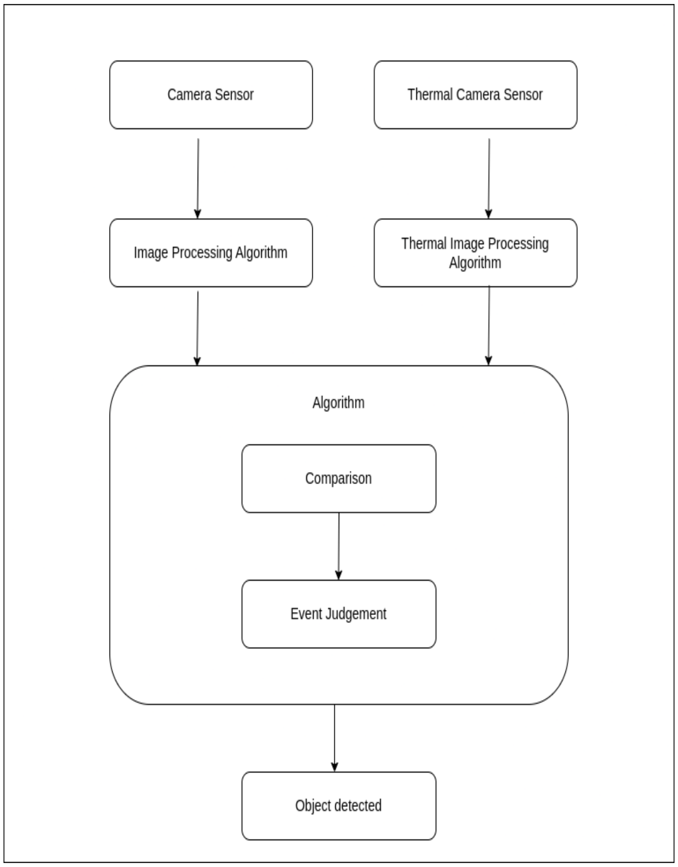

Fig. 1: Flow Diagram of proposed system

The main idea is to place both sensors at a distance to get better results in harsh weather conditions. Our system will get live data from two sensors, which are a camera and a thermal camera. The camera will get live video, which will be processed first for noise removal. Then, with the use of an object detection algorithm (like YOLO5), the object will be detected. At the same time, the thermal camera will get an image of the object's heat signature. The image will be sharpened further, and the vehicle's edge will be obtained using logical operations. Extraction of pixel values near the edges of the vehicle will be added to the spatio-temporal image. Then, the higher value pixels of each region in ST-Image will be deleted. Finally, the remaining zonal region is detected. The data from both sensors will then be combined. For this purpose, an algorithm that makes use of machine learning will be used.

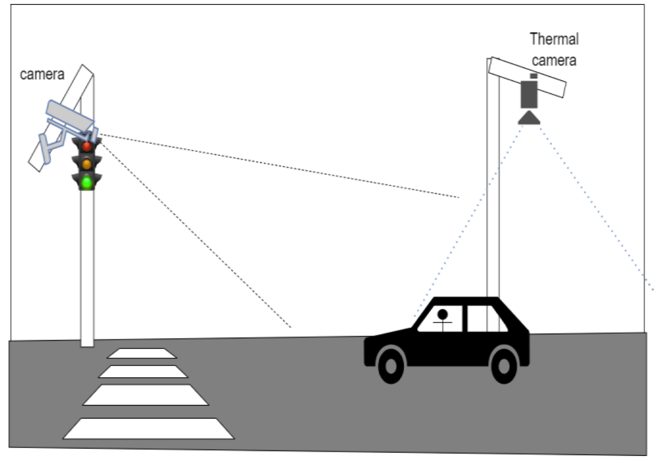

Fig. 2: Proposed design

Figure 2 depicts the vehicle detection system that will be implemented in a real-world scenario. Here we are using a two-sensor setup, one for live digital imaging and the other for thermal imaging. Both these systems are placed at some distance from each other. The camera will capture live video of oncoming traffic on the road. At some distance, a thermal imaging sensor will detect the heat signature of the objects on the road from above to minimize the viewing distance and get an accurate thermal image for detection. Both sensors will be capturing live data about the traffic on the road. Then the data from both of these sensors will go through pre-processing to remove noise, which will provide clean data for further processing. After that, the data will be provided to an algorithm whose main task will be to merge the data coming from both sensors and then compare that data to make sure there is no object that goes undetected.

Working principle of algorithm

The algorithm will perform the following major steps:

1) The algorithm will get input from both the camera and the thermal camera as objects are detected by them separately.
2) The data of detected objects from both sensors will be compared, and any differences in the identification of objects will be searched for.
3) If both sensors detect the object, then no further process- ing needs to be done. However, if there is a discrepancy between objects, this event will be resolved using some threshold values.
4) In the event of a detection conflict, the detection result with the higher detection percentage between the two will be assumed to be true if the difference is significant.
5) Then the final result of detected objects will be generated.

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IV. CONCLUSION

We have proposed a new vehicle detection system that will combine computer vision and thermal vision and be more accurate. This research will not only fix the previous system's oddities, but it will also create a prototype for future improvements. In densely populated cities where traffic congestion is a big issue, this vehicle detection system will help to improve the current traffic situation. This system will help in tracking and identifying vehicle traffic in adverse conditions like bad weather and poor lighting. The system uses a thermal (infrared) camera to overcome the constraint of video image processing, which is its inability to accurately detect vehicles in conditions of bad weather like fog, smog, rain, snow, and poor lighting. On the other hand, a thermal camera can also only be accurate to a certain extent in adverse conditions, so we have proposed a system that will be a combination of both. These technologies will complement each other, as they will help remove each other's weaknesses. For further future study, we can also use the present weather state as one of the judgment criteria in our algorithm. We will work on the above-proposed algorithm in our future research endeavors, and we can also test this system by making use of test data.

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