Understanding the Perception of Road Segmentation and Traffic Light Detection using Machine Learning Techniques

Anusha A. Nandargi, Arun S Tigadi, Ashwini Bagewadi, Amey Joshi, Ajinkya Jadhav

Abstract: Advanced Driving Assistance System (ADAS) has seen tremendous growth over the past 10 years. In recent times, luxury cars, as well as some newly emerging cars, come with ADAS application. From 2014, Because of the entry of the European new car assessment programme (EuroNCAP) [1] in the AEBS test, it helped gain momentum the introduction of ADAS in Europe [1]. Most OEMs and research institutes have already demonstrated on the self-driving cars [1]. So here, a focus is made on road segmentation where LiDAR sensor takes in the image of the surrounding and where the vehicle should know its path, it is fulfilled by processing a convolutional neural network called semantic segmentation on an FPGA board in 16.9ms [3]. Further, a traffic light detection model is also developed by using NVidia Jetson and 2 FPGA boards, collectively named as 'Driving brain' which acts as a super computer for such networks. The results are obtained at higher accuracy by processing the obtained traffic light images into the CNN classifier [5]. Overall, this paper gives a brief idea of the technical trend of autonomous driving which throws light on algorithms and for advanced driver-assistance systems used for road segmentation and traffic light detection.

***Keywords** : ADAS, Traffic-light detection, Road-segmentation, Convolutional neural network.*

I. INTRODUCTION

Consumers in the world are very eager for the emergence of Self-driving cars, especially sake of the public. A self-driving car is a vehicle which operates without human intervention and every task performed is automatic.

Campbell et al. stated that modern autonomous vehicles can sense [2] the surrounding and can classify different objects of various types that come into its notice [2]. Later, it can interpret information to identify appropriate navigation paths while obeying transportation rules.

The year 1926 marks the beginning of the timeline of autonomous cars and 'Linriccan Wonder' being the world's first car controlled by radio waves. Remarkable progress was witnessed in 1980 when Mercedes-Benz's vision guided robotic van [2] was introduced. Since then the main importance was being given to vision guided systems like GPS, Lidar, Radar etc. Because of such implementations, this filed has seen a great advancements and progress in itself. Introduction of such driverless vehicles reduce the number of accidents every year. We can defeat the issue of Parking shortage with the usage of self-sufficient vehicles, as vehicles can drop the commuters to a correct place, afterwards return to get commuters when required. Consequently, the parking place problem can be decreased. Likewise, travelling time will reduce, as autonomous vehicles can go at higher paces with least chances of mistake. In the survey, an attempt is made to improve future autonomous cars by attempting to focus on the fields of road segmentation and traffic light detection which will improve the autonomous vehicle in turn. There are so many ways of improving autonomous car but focus is given on the main traits which assist the smooth running of autonomous cars. After monitoring the traffic scene there are two tasks to be done: Object detection: Object detection is inclusive of objects like traffic light detection, vehicle detection and pedestrian detection. Road Detection: Road detection includes road segmentation, road marking detection and lane detection. Road detection has the primary importance above all as the autonomous vehicle should know its path of navigation. In this survey, we are focusing on road segmentation and traffic light detection which help us improve the mobility of the autonomous vehicles.

A. Road Segmentation

We are currently focusing on road segmentation as it gives the drivable region to the vehicle's next movement. To monitor the traffic scene, cameras can be utilized, yet we face numerous issues with cameras like differences in appearance f road, picture clarity issues, poor visibility conditions so we switch to utilizing sensors.

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However, considering the above conditions, they are really hard to produce and simple to fall flat. Rather than passive sensors, for example, cameras, the most effective sensor is light identification and ranging (LiDAR). LiDAR sensor measures distance from it to an object by enlightening the object with laser beam and measuring the reflected light. In the process of taking the pictures from the LiDAR sensor, the autonomous vehicle should know every single component in the picture. For perceiving the components in a picture, we perform semantic segmentation, a technique for "deep learning" to differentiate and label the objects. Both real-time execution and power usage must be thought for the utilization of self-driving vehicles. Graphic-Processing Unit (GPU) [3] is a well-known stage to perform parallel-processing, however power utilization is normally high. FPGA board is picked over GPU because it expends limited power supply and perform gigantic parallel-processing [3].

There are many deep learning algorithms used to process the LiDAR input data for instance,

Semantic segmentation: Semantic segmentation is a deep learning calculation that connects a label or category with each pixel in a picture. The principle objective is to characterize each pixel of the picture into road or non-road.

Network-in-Network (NiN): A Network in Network-NiN is a run of the typical CNN architectural design comprises of a continuous arrangement of convolutional and the polling layers, alluded by certain authors as the feature extraction stage, trailed by various completely associated layers (as in a Multi-Layer Perceptron i.e. MLP) where the last layer executes the loss function. The preparation is performed utilizing stochastic gradient descent and the gradients are registered by the chain rule, precisely as in a standard MLP [4].

Binarized-normed-gradient (BING) technique and PCA-network (PCANet): A road marking detection and grouping dependent on AI calculations (machine-learning algorithms), focused on smart transport approach based on video. This methodology has two steps. The identification is finished utilizing the BING technique. PCANet is utilized for characterization/classification of objects.

Binarized-normed-gradient Feature for Detection: The BING highlights can be utilized to identify objects in a picture. The BING highlight is fitting for discovering road boundaries because the road boundaries have shut down limits and elevated angles over the boundaries. So as to name the articles in a picture utilizing the BING highlight, we have to prepare it utilizing training samples. In a picture, the road markings are the ones which are required so they are known as the positive examples and the background in pictures are the negative examples. The AI strategy inside BING is a linear Support Vector Machine(SVM).

PCANet: Considering the recognition outputs from the BING level, we fabricate a classifier- PCANet to sift through the unwanted pictures as well as perceive genuine road boundaries. This incorporates a multi-class SVM along with PCANet. By comparing all above algorithms, performing semantic segmentation to process the input of the LiDAR sensor is most efficient as it fulfills the criteria of both massive parallel processing and takes less time. A proficient equipment configuration is executed on FPGA board which processes every LiDAR input image in 16.9 ms [3] , comparatively which is quicker. This work is assessed utilizing road benchmarks of KITTI, this arrangement accomplishes great precision of segmentation of road.

B. *Traffic light detection*

Even the traffic light detection is done by taking in the input from different kinds of sensors or cameras and processing them based on different CNN based algorithms but the algorithms are slightly different as they are expected to be more efficient and faster. On-going researches are focused on utilizing AI or deep-learning strategies to prepare the model based on information.

Moreover, neural system based deep-learning models i.e. CNN models frequently accomplish preferable execution over the AI models dependent on Histogram of Oriented Gradients (HOG) highlights. It is fundamental because convolutional layers can extricate and take in increasingly pure highlights from the raw RGB channels than customary calculations(algorithms), for example, HOG. Nonetheless, the complex multifaceted nature of models of CNN is a lot greater than most AI calculations as well as heuristic calculations.

Also, enormous pictures are frequently utilized to catch broad perspectives for autonomous vehicles, and also utilization of binocular-camera increases calculation unpredictability. It is significant for the organization based on deep learning on TLD models in lower force and lower execution vehicle based calculation stages for autonomous vehicle or a driver assistance systems (DAS).

Not quite the same as past research endeavours that assess their performance on the PC stages, a continuous model of traffic light detection that joins lightweight CNN classifier and a heuristic vision-based module is proposed. Heuristic identification calculation attempts to fetch entire candidate region of interest and the model of convolutional neural network is put under process to bring power less than ten watts. A self-developed model comprising of main components of NVidia jetson tx1/tx2 and FPGA boards [5].

An on-going traffic-light identifier which joins the heuristic calculation and also the CNN-based classifier was presented. The inclination towards the collection of traffic lights which is accessible and an efficient dataset was examined. Along with the help of genuine data and data acquired from other sources, on-road test assessed on two self driving vehicles such as car and bus.

II. REVIEW CRITERIA

Road segmentation has been concentrated with a wide range of sensors and calculations in the course of 10 recent years. Prior, analysts utilized designed component descriptors to distinguish the road from erroneous background. Around then, prominent sensor like camera and highlights were frequently created dependent on brightening as well as shapes from pictures, which prompted low accuracy and the execution varied as for various conditions of light and road view. As of late, two significant strategies have been researched to defeat issues of features selected by users in pictures. First, the utilization of ML to structure a compound and efficient component descriptor. Second one, the utilization of scale invariant sensor rather than camera. A well known scale invariant sensor is LiDAR sensor.

Researched works attempting to join the above both the methods and implement ML to data handling/processing.
Numerous outcomes demonstrated great accuracy, yet their handling time is long enough to be used in applications in actual-time. For self-driven vehicles, road-segmentation ought to be executed on ongoing sources, for example, field-programmable gate array. A system was brought forward to identify the road markings of the street on TK1 portable GPU stage which possessed run-time of 2.5Hz. Thus, researched work was put forward for the neural system to portion many objects inclusive of vehicle, passerby, asphalt and the resolution of 480x320 pixels on GPU TX1 platform with a run time of 10Hz.
A paper which was published in the year 2012 in IEEE for On-going project on Traffic lights in Detection and Evaluation provided a summary four different approaches to Traffic light detection from group of four authors. Later, after an year, a paper on Euclidean Distance Transform and Local Contour Pattern based Traffic Light Detection and Tracking was published and it mainly focuses on improving the performance of recognizing the real-time traffic light, detection distance and accurate results. An approach in combination used the color and knowledge of contour for traffic light detection. A paper on A Deep Learning based Traffic Lights: Detection, Tracking, and Classification [6] was an approach using deep-learning for detection of images with a resolution of 1280 × 720 pixels related to traffic lights in the year 2017. Reviewing the two papers of the same field published in the same year i.e. 2018 but for two different publications, Traffic Light Detector for autonomous-vehicles based on Deep-CNN and Efficient Color Space for Recognition of Traffic Light on the basis of Deep-Learning for IEEE and Hindawi respectively. The earlier discusses Traffic-Light detection for self-driven vehicles using hardware model, CNN concept and also on-road testing is carried out and the later, an approach using deep-learning for detection of images of traffic lights having a resolution of 1280 × 720 pixels. Traffic light detection system based on Deep-learning that comprises of pre-processing, neural-network processing and post-processing.

III. TECHNOLOGY USED

A. LiDAR

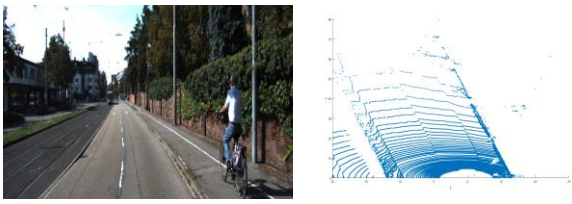

Figure1: An image of camera view and the corresponding LiDAR points

- Light Detection and Ranging also called LiDAR.
- LiDAR sensor measures the distance to a target by sending laser light to the target and measuring the reflected light with the same.
- Autonomous vehicles use LiDAR sensor for obstacle detection and to travel safely through roads.

B. FPGA

A field-programmable gate array (FPGA) is a circuit which is designed in such a way, that a client can design it after manufacturing, therefore the term "field-programmable" is used in its name. The FPGA setup is accomplished by using a Hardware description language (HDL). FPGAs contains a many number of logic blocks which can be programmed, that permit the logic blocks to be "wired together.

C. KITTI Road Benchmark

It comprises of dataset and benchmarks for PC vision inquire about in setting of self-driving vehicles. The dataset has been recorded in and around the city of Karlsruhe, Germany utilizing mobile platform. The dataset has been made for PC vision and machine learning research on sound system, optical stream, semantic segmentation, and so on.

D. Semantic Segmentation

Semantic segmentation is a deep learning algorithm whose goal is to mark and label each pixel in a picture. It is utilized to perceive and label a collection of pixels that structure various categories. For instance, a self-driving vehicle needs to distinguish vehicles, pedestrians, traffic signs, pavement and other road highlights.

E. Colour Spaces

The major module in Self-driving vehicle and Driver Assistant Systems is TLD i.e. Traffic light Detection. There are various other models other than RGB for representing colours numerically. These models refer to as colour spaces because most of them can be mapped into a 2D, 3D or 4D co-ordinate system. Basically, RGB shows percentage of Red, green and blue hues mixed together whereas colour space models describe colour by their hues(shade of colour), saturation(amount of gray-scale) and luminance(intensity).

F. Histogram Of Oriented Gradients (HOG)

It is used for feature descriptors, describes elementary characteristics such as the shape, the colour, the texture or the motion. The description takes place with the help of signal processing.

IV. METHODOLOGY

A. Road segmentation

We are essentially focusing on road segmentation, as the vehicle should know its way of route. The objective of road segmentation is to perceive and mark the road, which is likewise called free space. The information originates from various sensors for this situation is LiDAR. Self-driving vehicles can utilize LiDAR sensor for obstacle detection. LiDAR sensor emits laser rays to measure the. To process the LiDAR input data and name the objects in the image taken, semantic segmentation is processed on an FPGA board. FPGA suits to the condition because it consumes less power supply. Further, FPGA is designed in such a way that it can execute massive processing of any data. Along these lines, we focus on the LiDAR put together road segmentation calculation with respect to an FPGA board.

An effective hardware configuration is designed on the FPGA that can process and perform semantic division on every LiDAR scan in 16.9ms. The proposed arrangement is assessed on KITTI benchmarks and accomplish agreeable outcome. The output is in the form where every pixels is named and is displayed.

Three stages of proposed calculation:

- Pre process
- Processing of neural networks
- Post process

Pre process:

In this, the data points of input image are arranged in a three dimensional fashion M x N tensors and C channels so that so that convolutional neural network can be performed with ease, as an input image has been divided into pixels. Spherical view of LiDAR sensor is utmost suitable in this scenario.

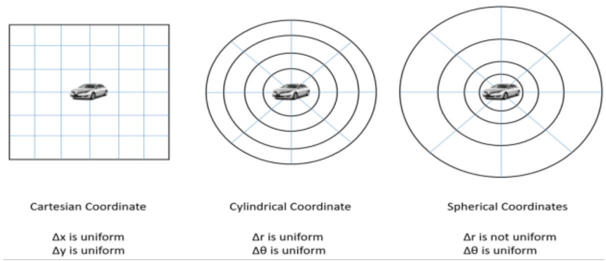

Figure 2: Grid projection to ground from Cartesian coordinate view, cylindrical coordinate view, spherical coordinate view,

Processing of neural networks:

In self-driving, the traffic perceptions done on embedded systems.

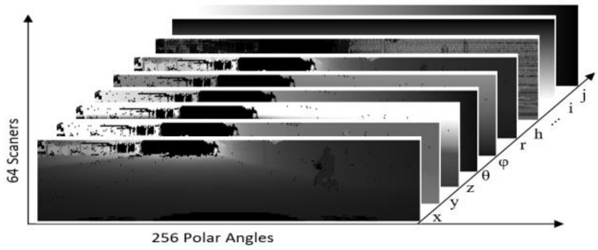

Figure 3: The neural network of input map with 16 channels

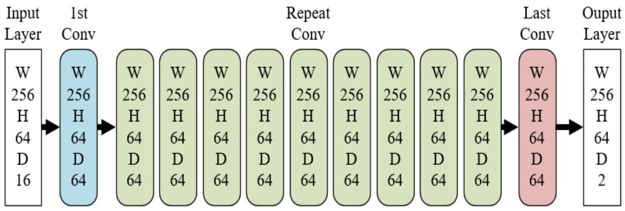

Figure 4: Architecture of the CNN

Apart from blue shaded 1st layer and pink shaded layer, the middle layers are repeated which are similar. They are called hidden layers. It has 9 repeated layers because it can extract many minute features.

Convolutional Neural Network

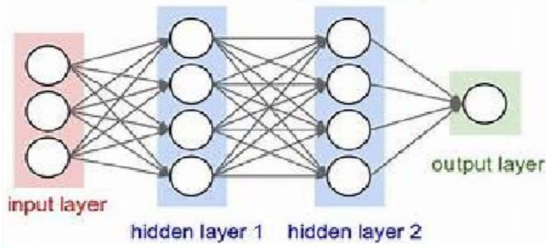

Figure 5 - Convolutional Neural Network

To get an understanding of the above architecture in figure 5 here is a brief explanation on CNN.

- Convolutional neural networks also called as CNN has hidden layer called convolutional layer.
- A convolutional layer accepts an input, processes and changes the input into one way and the changed input is obtained.
- This process of changing is called convolutional operation.
- Convolutional layer detects patterns in images.
- The circles in the above figure are called filters. These filters are the one which detects patterns.

Let us try and understand how CNN works with the help of an example. Let the image of the surrounding be taken form a LiDAR sensor and CNN (semantic segmentation) has to be performed to detect the road from the image. If the input image is of the resolution 2x2 for instance, then the number of filters to be used in input layer is 2x2=4. Therefore the input layer will have four filters. The images of road has to be taken in all possible angles and with different resolutions and fed into hidden layer 1 in the above figure as dataset. The filters in input layer are compared with each filter in the hidden layer and when a filter matches we get an output saying if it is a road or not.

Post process:

In this part, yield acquired from the neural system are reflected back to target views, for example camera view, for checking its exhibition. Figure 6 shows a case of the road segmentation results.

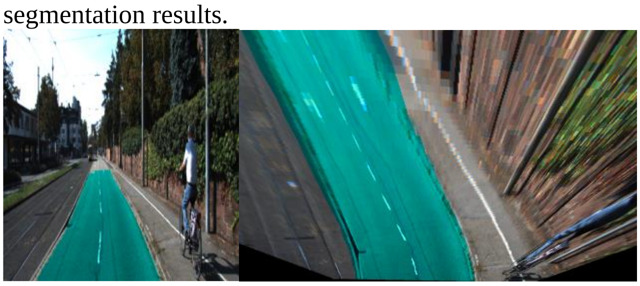

Figure 6: Drivable region as output after processing of neural network

To determine the boundary of the drivable region that is road, the angle θ in each points, which corresponds to every segment of the neural network system output, are chosen and projected back onto the target view as output. To assess the execution of above method, we coach the system on KITTI benchmarks. The actual handling period of the neural system processing done on the FPGA is 16.9ms.

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B. FPGA Design Hardware Architecture Of Road Segmentation

The figure of convolutional layer is shown below. There are 64 memories of 256k bit size. The enormous three-dimensional convolutional network is segregated into 64 parallel two-dimensional with each 2 filters intern.

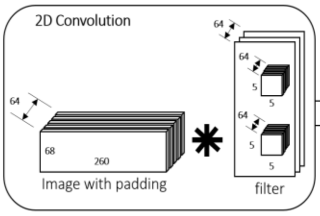

Figure 7: FPGA structure Hardware design for use of convolution layer.

An implementation of 2D convolution is done, and executed on Xilinx Ultra Scale XCKU115 FPGA, with expected operating frequency of 350MHz. The two-dimensional convolution takes about 18,000 cycles of clock, and is executed in 16.9ms.

C. Implementation results:

An implementation of 2D convolution is done, and executed on Xilinx Ultra Scale XCKU115 FPGA, with expected operating frequency of 350MHz. The two-dimensional convolution takes about 18,000 cycles of clock, and is executed in 16.9ms.

D. Traffic light detection(TLD)

1) Heuristic Algorithm based on Vision: These being most principal strategies for light recognition of traffic, also pertinent systems could be summed up as follows: a) Plotting raw pictures in various shading color spaces. b) Finding the blob as indicated by the shape's filter, edge, solid circle, and other geomorphological attributes; c) Merging both color as well as morphological highlights.

2) Machine learning-based calculation (algorithm):

To naturally choose and advance a lot of traffic signal dataset collection, scientists/researches attempted to manufacture models based on AI and ML for traffic signal light identification/acknowledgment in data-driven procedure. The proportions and effectiveness of conventional ML based TLD(traffic light detection) techniques appropriate for vehicle's condition. Nonetheless, primary issue is basically the capacity to learn as low performance even to think about covering rich highlights in image processing. In addition, significant data may lose all sense of direction in HOG features' extraction through Red-Green-Blue or various shading color space. Both above issues has the ability to prompt lower detection precision where open air i.e. outdoor and rapid situations are present. The authors join the Histogram Of Gradients-based Support Vector Machine for detection of traffic light and light state CNN acknowledgment. Profound TLR likewise examined diverse configurations in managing dataset of traffic light. The on-going quick advancement of TLD on basis of deep-learning gains by the accompanying two perspectives: 1] many features can be separated from the convolution layer than HOG, and 2] the many-layer structure of the Convolutional Neural Network model can learn comparatively more elements blends just than basic ML models making conceivable to learn whatever number potential examples as could reasonably be expected from mass information and to accomplish better recognition execution as indicated by the information gathered from real road conditions [5]. For traffic signal's light detection in self-driven vehicle condition, fundamentally two difficulties arose. 1] Broad-angle camera is frequently utilized on driverless vehicles for catching broad pictures before the vehicle, and this can prompt high-definition raw pictures, (for example, 1292 × 964) yet bigger utilization of computer. 2)Taking into consideration supply of power as well as dependability of hardware as well as software, customary computer isn't appropriate for self-driving vehicular condition. To overcome the above problems, A plan of a vehicular stage "Driving Brain"– with 4 Nvidia Jetson TX1+ 2 FPGA chip is finished [5]. Power utilization of a chip of the platform is low as ten watts as mentioned earlier. Entire component devours under 100 W. Taking into account overall scan of the Convolutional Neural Network model is not efficient, a heuristic algorithm based on vision to choose the candidate region of traffic light as well as afterwards differentiate all available lights and invalid objects with the CNN classifier is build. Entire line of the detector appeared in Figure.

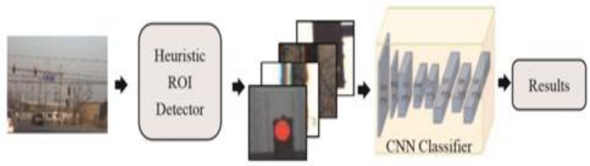

Figure 8: Pipeline of the ongoing traffic identifier: 1) Region-Of-Interest model detects the initial attempts for locating conceivable traffic-lights (inclusive of background); 2) little CNN classifiers' attempts for recognizing correct category of every Region of Interest and results are obtained [5]

E. Traffic light's dataset collection

Biased Sampling process in traffic light dataset: Issue of the unstable dataset has for some time being concentrated in knowledge discovery. As of late, it is likewise discovered models prepared on these datasets additionally will intensify the bias which is in existence. Leaving appropriately measuring as well as reducing dependence of these co-relations, not entirely prepared models can be obtained; expansive wide selection of these models may prompt major issues in true applications and particularly in self-driving. Therefore, biases caused under such conditions are:

- Bias is brought with traffic-rules: at the time of data collection, car or any other self-driving vehicle had to slow down and wait when the red light turns on, and pass-over the convergence at green light signal; this prompts increasingly red-light examples
- The junction point sorts the collection ways (routes) which have traffic signals of various types, for instance, such as intersection in shape of T might not possess turn left light but may affect in dataset collected as it may influence light distribution of same kinds gathered

• The prior-set length of every single light of various intersections possibly are different. For instance, the span of red colour signal is frequently long as compared to green light in many junctions in the country-china

• For half-automatic denotation or labelling, the limits' setting, (for example, estimations regarding colour spaces, size of jumping box, and so on.) might prompt various output. Fine-tuning datasets Because of the information based training as for models on deep-learning, very less samples come under-prepared model on relatable categories and which might prompt amplifications of predispositions in testing and genuine deployment of world. Not quite the same as the examinations that target improving precision, we additionally think about how to decrease the above predispositions during data collection and afterward produce an efficient data for training the model as possible like utilizing the accompanying strategies: 1) Very nicely structured road which consists of various types of signals 2) Maintaining of comparative period of gathering information in sort of traffic light signals 3) Manually adjusting various examples for the data.

F. Evaluation

Assessment of the ROI: A portion of the relatable ROI detectors segregates red and green lights as per pixels' estimation of channel-H, also manage the lights by various procedure modules. In the framework, ROIs are treated that contain various types of lights as the same; subsequently, the exactness of our ROI detector can be assessed. The primary deficiency of this identifier, that would not recognize articles along the similar H-S esteems as signals of traffic light, for example, vehicle lights, also different items as covers of green and red as represented in Fig.

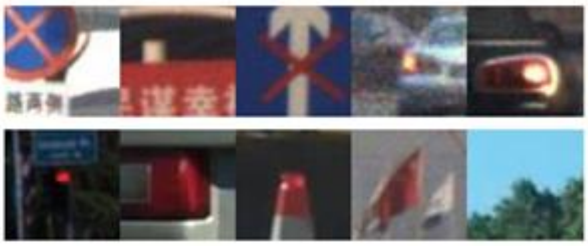

Figure 9: Examples of erroneously identified ROIs

Assessment of the Convolutional Neural Network classifier after candidate-ROI [5] recognition, gathering of little Region of Interest from unprocessed pictures. At that point, a model of CNN to recognize every possible lights are utilized. So as to assess this said model, it is contrasted and notable CNN models, (for example, Alex Net, Dense Net, Google Net, and Res Net intended for light recognition.

G. Implementation Results

Aim was focused upon undertaking detection of traffic light; subsequently vehicular control, navigation along with path/wait identification frameworks is disregarded. The traffic light detection module gets activated or turned on when the signal post is less than 50m and turns off as soon as it passes the road junction or signal post junction. Now, when this red light is detected while the turning on of the module, the vehicle stops or when it is close to the stop line.

Figure 10: 1) Self-driving vehicle "RAETON" 2) "I-BUS"

Above are the two vehicles utilized for real-time testing on road. One is a driverless vehicle "RAETON" and other is a transport "I-BUS". The dataset assortment and the testing were completed in the city of Beijing.

V. RESULT AND DISCUSSION

Concerning segmentation, system is prepared by KITTI recognition of road data and assessed on the testing standard. Additionally, the suggested completely associated system based on neural was executed upon a Field Programmable Gate Array on an on-going low power process, resulting into the handling of just 16.9ms for every LiDAR check. A functional traffic light recognition framework that consolidates the well-known Convolutional Neural Network model and the ROI based heuristic detection algorithm calculation to fulfil the prerequisite of Autonomous hardware platform (NVidia Jetpack TX 1/2 -'Driving Brain') [5] is introduced. Therefore, a superior recognition of traffic light and road segmentation module is created which can deal with nice resolution pictures for ensuring wide view and fulfilling low frail computer operational vehicle hardware. A real on-road testing is being conducted. However, the present module despite everything has to improvise from the accompanying perspectives in coming days. 1] The ROI on heuristic model identifier could be improvised from basic ML model. 2] Preparing and testing the present modules, the present set of data should reach out along with additional traffic light, road classes and also pictures even from bad conditions of light. 3] However, the present design model has the ability to improve with recent advancement methods in deep learning. By consideration of both the above points and also by the introduction of V2I-Vehicle-to-Infrastructure communication [5] in the near future, self-driving vehicles would become more efficient.

VI. CONCLUSION

In 2015 there were an expected 1.3 billion engine vehicles on the world's streets and with developing wealth in creating economies that number is relied upon to take off to more than 2 billion by 2040. Indeed, even with new streets and sidesteps, this ever-expanding level of traffic could rapidly surpass the capacity of our street systems to adapt in many occupied zones, for example, urban areas.

Hence, traffic light recognition and road segmentation facility in self-driving autonomous vehicles along with several other added features as this, will improve traffic conditions on street and accordingly adding to a superior framework and better infrastructure.

To close, the fundamental things for example Road Segmentation and Traffic light Detection help in making a vehicle of more advanced type in Driver Assistance Systems.

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Have a working experience of 11 years in the department of E and C. Received my Doctorate Degree in Electrical and Electronic Science in the year 2020 from VTU, P.G Degree in VLSI Design and Embedded systems from VTU in 2008 and U.G Degree in E&C from S.D.M CET Dharwad in the year 2006. Fields of interest are Low power VLSI design, Automotive Electronics, FPGA Design, Memory controllers, arbiters, multiport memory design, Real time system design and Operating systems. Attended 6 International Conferences and published around 24 papers in International Journals. Worked as reviewer of peer reviewed journal. Guided around 9 UG and 9 PG projects. Worked as a editor for Handbook of Automotive Electronics , Autosar and Infotainment.

Ashwini Bagewadi, a final year student pursuing degree in electronics and communication engineering from K.L.E DR. M.S. Sheshgiri College of Engineering and Technology. Udyambhag, Belagavi, under Visvesvaraya Technical University, Karnataka , India. I have performed four mini-electronic projects in College Project Expo for two consecutive years. Attended workshop on 'PCB Design' at KLE Dr. M S Sheshgiri College of Engineering and Technology, Belagavi. Also, participated in workshop on 'Machine Learning with Python' organised by ECSSA of KLE DR. MSSCET, Belagavi. Currently, working on Smart gardening and agricultural system-plant disease detection using machine learning. I have devoted myself in many technical and cultural activities conducted in college and outside. Also, I had the privilege of visiting ISRO, Bengaluru under the technical visit which was initiated by college.

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