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Autonomous Lane Detection and Lane Tracking Decision Making

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Certificate of Approval

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

(Signature of the Supervisor)

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Declaration of Authorship

This is to certify that the work presented in this thesis is the outcome of the analysis and experiments carried out by Md. Beheshti Kabir, Md. Asif Ahmed Amit and Md. Abdullah Ath Tashrif under the supervision of Mr. Mirza Fuad Adnan, Assistant Professor, Department of Electrical & Electronic Engineering, Islamic University of Technology (IUT), Gazipur, Bangladesh. It is also declared that neither of this thesis nor any part of this thesis has been submitted anywhere else for any degree or diploma. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given.

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Dedication

We would like to dedicate this thesis book to our families, and everyone who have given us unwearied support throughout the entirety of our existence and born testament to our efforts and failures, yet who always stayed by our side, especially during the harsh times.

Acknowledgement

First, we would extend our deepest gratitude to the Almighty Allah, our Creator, who had created us and instilled inside us, the intellect to educate ourselves with the knowledge of the world and thus conduct our research on this thesis successfully. Foremost, we are very grateful to our respected supervisor, **Asst**. **Prof. Dr. Mr. Mirza Fuad Adnan,** Assistant Professor, Department of Electrical & Electronic Engineering, IUT, for his constant guidance and encouragement towards exploring the field of Electrical and Electronic Engineering. If it had not been for the inspiration he provided us, we would have lost track of our way on this long journey.

Again we would like to mention **Mr. Mirza Fuad Adnan** sir. His motivation, suggestions and insights for this research have been invaluable. Without his support and proper guidance this research would never have been possible. His valuable opinion, time and input provided throughout the thesis work, from first phase of thesis topics introduction, subject selection, proposing algorithm, modification till the project implementation and finalization which helped us to do our thesis work in proper way. We are really grateful to him.

Finally, our deepest of gratitude goes to our family who always listened to our sufferings and enchanted us with their delightful words. Last but not the least, we would like to thank our friends who always supported us through this journey.

Contents

CHAPTER 1

INTRODUCTION

1.1 Getting to know

In the field of automobiles, self-driving cars are the latest technological development. As we are moving towards a future where vehicles are to be driverless, this technology is getting extremely evolved time to time. Bangladesh, especially the capital Dhaka, is renowned for its traffic jam. The other major growing cities of this country are also lining up with this problem. The traffic congestion due to the overpopulation in a narrow area is not only the problem. Here, the traffic rules are often broken by the citizens, mostly by the drivers. For a third world country like Bangladesh, with the likeliness of lack of parking space, roads being not up to the standard that need to be, Dhaka along with the other major cities of the country is becoming a huge abruption to progress of self-driving vehicle concept.

1.2 Issues

1.2.1 The overview of issues

There are some issues to be noted in the case of self-driving cars for the perspective of a 3rd world country like Bangladesh. Some are highlighted in a paper released by World Health Organization (WHO) [1]. According to the paper, There are tremendous number of non-motorized vehicles running in Bangladesh which are one of the reason for slowing down pace of traffic in the main roads. Even though the capital Dhaka has divided the ways of motorized and non-motorized vehicles (i.e. – rickshaw) it is not visible even in the entire city. The paper has also mentioned about the over involvement of large vehicles & pedestrian Jay walking. Another issue to be mentioned in terms of self-driving car for the perspective of Bangladesh can be that the country contains a large number of pot holes to be in an inappropriate place [2].By collecting information from another study, it can be stated that most of the traffic jam that take place contain three vital reasons [3] .

i) Pedestrians walking on the roads unnecessarily
ii) Irregular & abruptly car parking
iii) Street Hawkers accommodating themselves on the footpath forcing people to jay walk by the main road.

To get the upper hand of self-driving vehicles, the above mentioned problems need to be solved and that can also be done by the proper improvisation of traffic rules, getting the right vehicles on the roads and making the drivers abide by the law with proper justice. As a developing country of this region, Bangladesh is quite welcoming to digitalization and these upgrades but this too will require time to be properly applicable. The issues are broken down from the other end's point of view on the next segment.

1.2.2. The breakdown of Issues

a. Parking

While the other developed countries contain a fluent management system regarding the vehicle parking spots, when it comes to Bangladesh it is seen to be quite low in terms of numbers [1]. Also in the case of the drivers it is quite evident that they contain a tendency to park the vehicles on the side of streets, resulting in making the streets more narrow which leads to congestion of traffic. This happens due to mismanagement of the traffic system as well as the lack of parking spots. So when there is a crisis of a proper parking spot even in the capital, it is quite unthinkable to run autonomous vehicle in this particular city suddenly.

Source: The Daily Star

b. Congested Roads

As the cities of Bangladesh are densely populated, there are a vast numbers of vehicle running through the entire city in a short space. So even if there is no traffic jam visible, a huge number of cars are bypassing at a time. So during the time of staying put in a signal the driver tries to keep cars as ahead as possible which leads to a more cramped area with vehicles. So even when the lights go green, it is not easy for everyone to forward at once as it takes time to move out and some specific space without causing a collision with the next car. This is the case which we cannot allow for a self-driving vehicle. Either this problem needs to be solved immediately and then the system can run or it is quite visible that the problem cannot get vanished easily at once. So self-driving vehicle practically becomes challenging and contradictory to the situation.

c. Inappropriate Roads

Keeping the evidence from the paper published in 2004 [2], in Bangladeshi cities are
the victim of waterlogging problem. As the end result, the roads get broken after a few months of inception, leaving potholes and fractured spots anywhere. The drivers in the country frequently change their lanes, brake unexpectedly to avoid strolling over these spots. that is very tricky for present day self-using vehicles when we consider that they're now not used to those sorts
of roads. The vehicles may run over these spots and reason harm to it and its passenger inside the manner. No need to extend to agree on the fact that the surprising lane converting and
braking would possibly confuse the cars that could result in road accidents.

Location: Dhaka, Bangladesh, during rainy season

Source: The Daily Star

d. Lane Changing Tendency

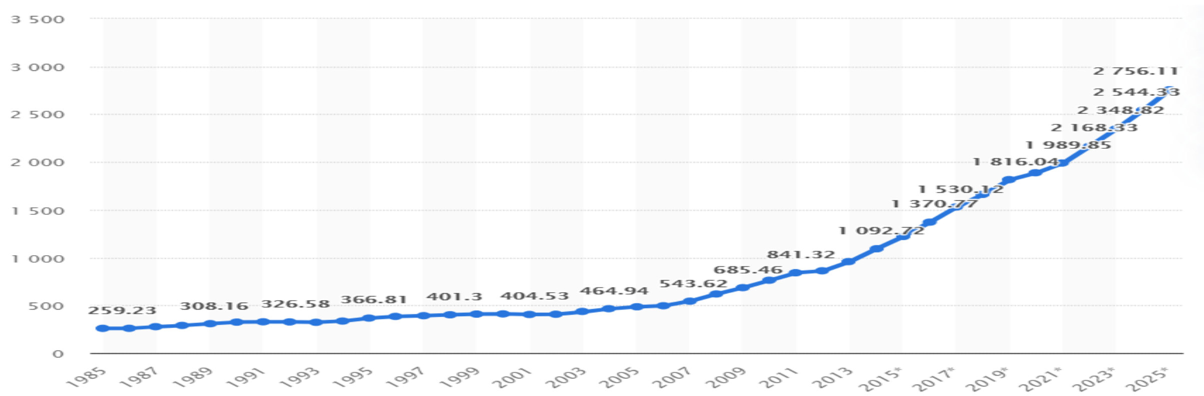
From the drivers point of view as there is traffic congestion which causes not reaching on a particular point in time or even reaching with a specific amount of delay, which causes a restlessness. So most of the drivers of Bangladesh contain a tendency of overtaking the next vehicle which seems to be running at a lower speed. Now, even if that particular car is running along a suitable speed, everyone has a tendency to go ahead of each other. To perform this overtaking incident successfully it is required that the driver needs to go out of his lane and move faster, after getting space then come back to that particular lane again. So for a certain amount of time it remains like this that two vehicles going on the same direction occupying two lanes entirely, which is very risky in terms of highway as most of the roads do not contain dividers and this increases the chances of accidents vastly. Most of these highway accidents that take place contain this reason. Coming down to self-driving cars, it is operated physically based on the position of lanes. So someone else overtaking that particular vehicle is not a normal incident. This can cause some severe malfunction which may lead to a major accident.

e. Mismanagement

From the perspective of the capital of the country, after some particular time of the night there are least number of traffic police present at night after 11pm. The heavy vehicles (i.e. Trucks, Cavard Vans) are released by 10pm. So after that period there are always scopes for traffic mismanagement and callous driving from the drivers end due to low monitoring. This is very alarming for welcoming the self-driving cars. Because it requires one certain management to operate properly. Haphazard road condition is heavily contradictory to its application.

f. Expenses

Lastly, for a 3^{rd} world country like ours expenses for a self-driven car is quite vital. According to the survey done by Statista the chart graph below shows the GDP of the country (in USD).



With this much income on average if looked on to the prices of self-driven cars in BD,

New Tesla Car Prices in Bangladesh	
Latest Tesla Models	Price Bangladesh
Tesla Model S Plaid Plus 2021	11,759,160
Tesla Model S Plaid 2021	10,079,160
Tesla Model X Performance 2021	8,399,160
Tesla Model Y Performance 2021	5,039,160
Tesla Model Y Standard Range 2021	3,527,160
Tesla Model Y Long Range 2021	4,199,160
Tesla Model 3 Standard Range Plus 2021	3,191,160
Tesla Model 3 Performance 2021	4,619,160

Source: www.ccarprice.com

It is quite evident that even if we put aside the fact for management issues & roads not being suitable, even the lowest price for the self-driven car is too much for a general citizen for this country. As we know the system does not run exclusively, means it requires the other vehicles to be self-driven as well, maybe in far future this system can be considered but in near this is quite impossible considering all the perceptions of Bangladesh.

1.3 A Different Solution

1.3.1 Overview

As the whole world is progressing through a developing country like Bangladesh will fall behind if we are not welcoming to the changes of the world. But as seen from the previous discussion it is quite obvious to the fact that the entire system of automated vehicle cannot be applied all at once. So there is a different solution thought on this contradictory problem. Neither making everything automated all at once, nor keeping everything manual and staying put while the outer world proceeds. The solution is a driving assistance system. That embraces the automation also can be implemented in this region. In short we have designed a driving assistance system that will tell the driver to stay in lane and will keep notifying the vehicle's position time to time to the driver. So the vehicle does not become entirely driverless, also with the proceedings of the world a partial application of automation is here.

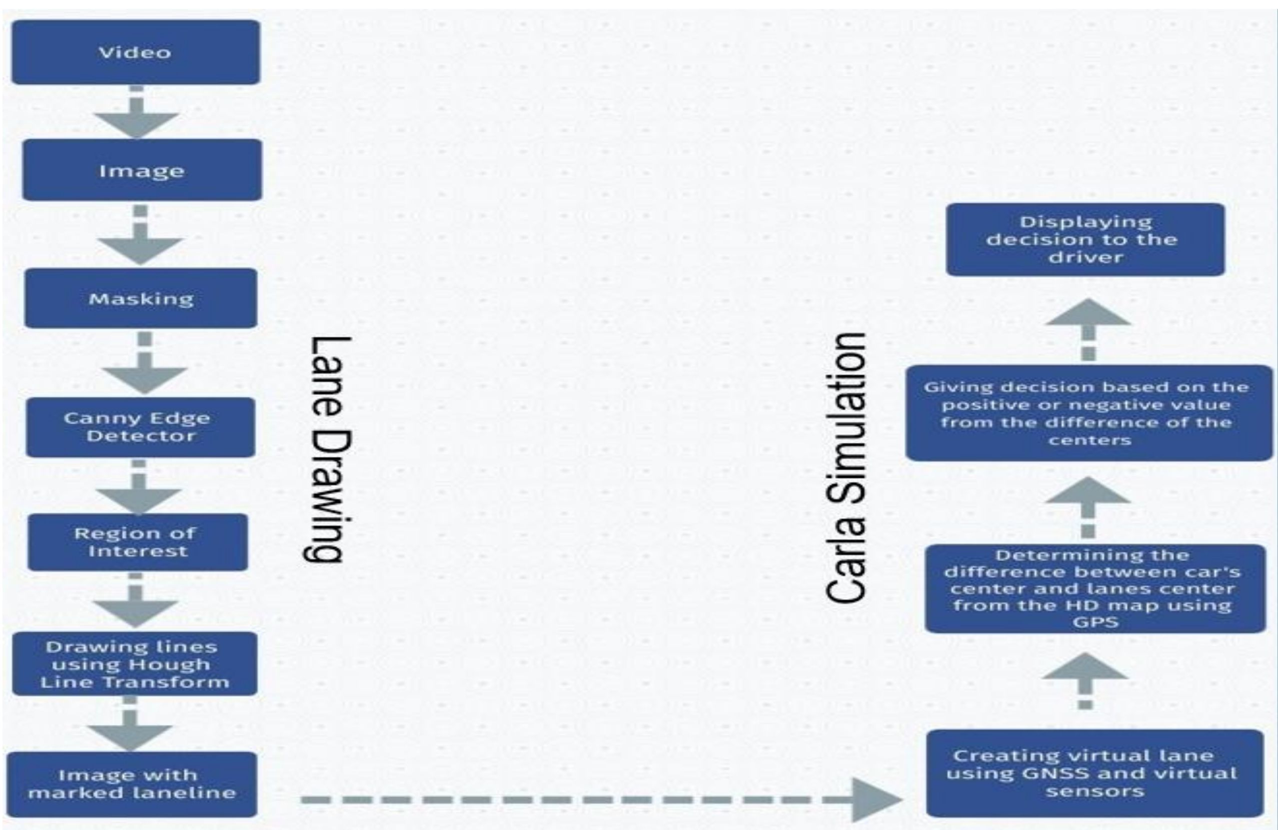


Fig: Overview of designing the entire driving assistance

Lane line detection is a very critical spec for autonomous vehicle and it is a part of the entire self-driven car module. The concept here is used to describe the path for self-driving cars and to avoid the risk of getting in another lane. As stated above, staying in lane will create more organized and risk-free platform for the entire transportation system. With this driving assistant, the drivers will be notified time to time to move towards a certain direction so that they can stay in the lane. Whenever they are out of it there comes the notification. This increases concern & creates a safety net from the driver's perspective.

1.3.2 Breaking down the features

As of now we are running our transportation management system and the vehicle as well as manually as possible. With the driving assistance system and it being compatible to this region few things are broken down.

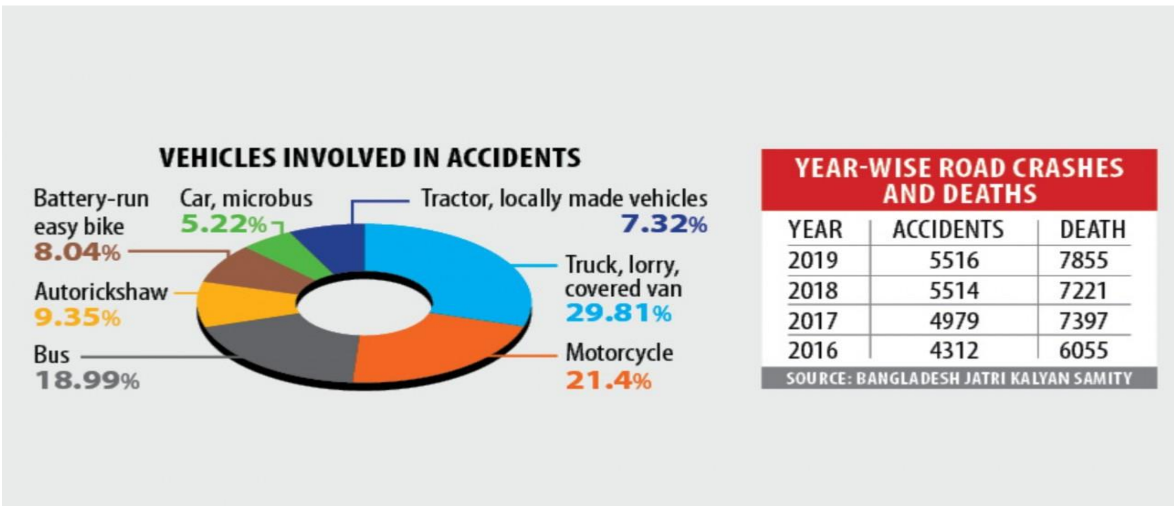
a. Minding the Expenses

As we want to proceed with the world also want to things being adjustable to our economy, we must keep the expenses of the system in our mind.
Here instead of buying a vehicle which is self-driven, only the GNSS & IMU sensors are used to trace the lane of the road and to send a signal of the current position to the driver from time to time. This will not only guide him or create an awareness to be in the lane but also the driver in these busy roads need always to be attentive; with the help of this a bit relaxation can be made. The assistant will not cost anywhere near the entire self-driven car expenditure thus making it affordable for the locals.

b. Risk Reduction

In a country like Bangladesh, traffic congestion and accidents have already become a part and parcel of the daily news. According to Dhaka Tribune survey, in 2020, 5,397 accidents on roads, railways and waterways killed 7,317 people and injured 9,021 others.

According to Bangladesh Jatri Kallyan Shamiti, the statistics of road accidents (till 2019) are stated as,



YEAR	ACCIDENTS	DEATH
2019	5516	7855
2018	5514	7221
2017	4979	7397
2016	4312	6055

SOURCE: BANGLADESH JATRI KALYAN SAMITY

From the stats it is quite easy to state the fact that with the country's rapid increment in terms of population and vehicles as well, the graph of road accidents and deaths due to that is going upwards as much as possible.

This driving assistant will come very much useful in terms to reducing this number as well as eradicating to some extent. Most of the road accidents occur due to the callous driving of the driver or lack of carefulness from the pedestrian's end. With this assistant the driver will not be leaving his lane and even if he's out of it, the system will notify immediately. Thus creating a whole lot space to reduce the risk of a person to vehicle and vehicle to vehicle opportunity of accidents taking place.

1.4 Limitations

With this emerging feature, even though this came out as a viable feature considering the situation or the current state of our country, there are some limitations to the system.

- The driver needs to understand the instruction time to time.
- Sometimes there are delays for update as the GNSS sensor lags several times.
- With the lag of the system proper lane changing instruction at any impulse might be the feedback from the earlier received signal which can cause a confusion for the driver

Even though there are some faults still to work on, it goes beyond saying that addition of this system will surely be an upgrade and the little investment will be worth the outcome.

CHAPTER 2

OpenCV

2.1 Library:

For detecting the lines from the live video we need to take picture from the video and make decision based on the picture. We will take pictures continuously and show the driver the decision comes from the outcome of the pictures take. For this we will work with different library in Matlab. We will use them for image processing and other process for the final outcome.

2.1.1 OpenCV:

OpenCV (Open Source Computer Vision Library) is a programming function library aiming at real time computer vision [4]. Initially it was developed by INTEL. Afterwards *Willow Garage* and then *Itseez* supported the vision of this library function. This is a free library and can be used in cross platforms. OpenCV added GPU acceleration for real time operation.

This library was officially launched in 1999 which was initially a project of Intel Research to advance CPU-intensive applications. In the library the main contribution was form the Intel Russia and Intel's Performance Library Team.

The main applications of this library is given below:

- 2D and 3D feature toolkits
- Facial recognition system
- Gesture recognition
- Mobile robotics
- Motion understanding
- Object detection

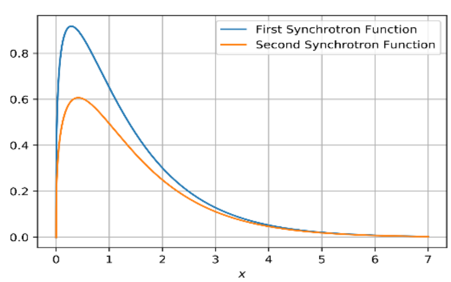
- Motion Tracking
- Structure from motion (SFM).

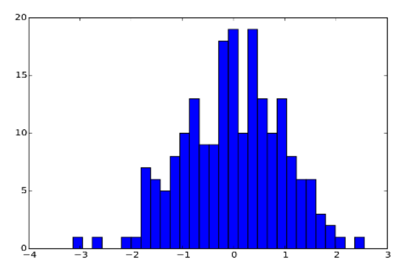
To support some of the above areas this library includes a statistical machine learning library that contains:

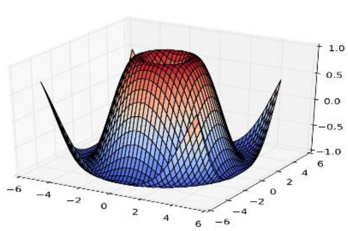
- Boosting
- Gradient boosting tree
- Random forest
- Deep neural networks (DNN) [5]
- Support vector machine (SVM).

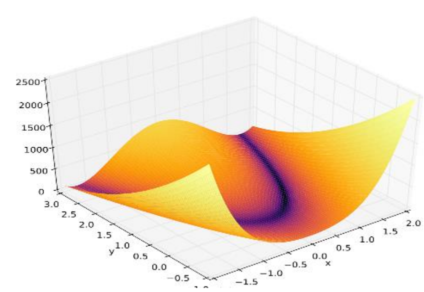
2.1.2 MatplotLib

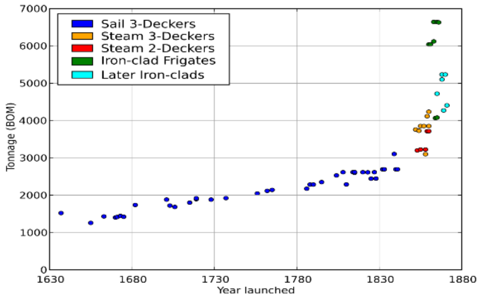
This is a library for plotting in Python programming language and its numerical extension in NumPy. Using general-purpose GUI toolkits, it provides object-oriented API for embedding plots into applications. *John D. Hunter* is the original writer of this library function. Afterwards *Michael Droettboom* was nominated as matplotlib's lead developer shortly before John Hunter's death and further joined by *Thomas Caswell*.

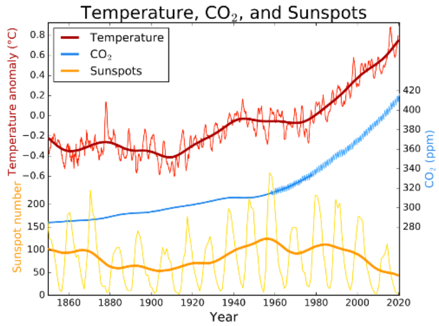












This are some examples of the matplotlib library function.

2.1.3 NumPy:

This is a library for the Python programing language, adding support for the large, multi-dimensional arrays and matrices, along with a large collection of high-level mathematical functions to operate on these arrays [6]. *Jim Hugunin* was the main creator of this library. *Travis Oliphant* developed this function by including competing Numarray into Numeric with tremendous modification. This is a free software and has many contributors.

2.2 Theorems:

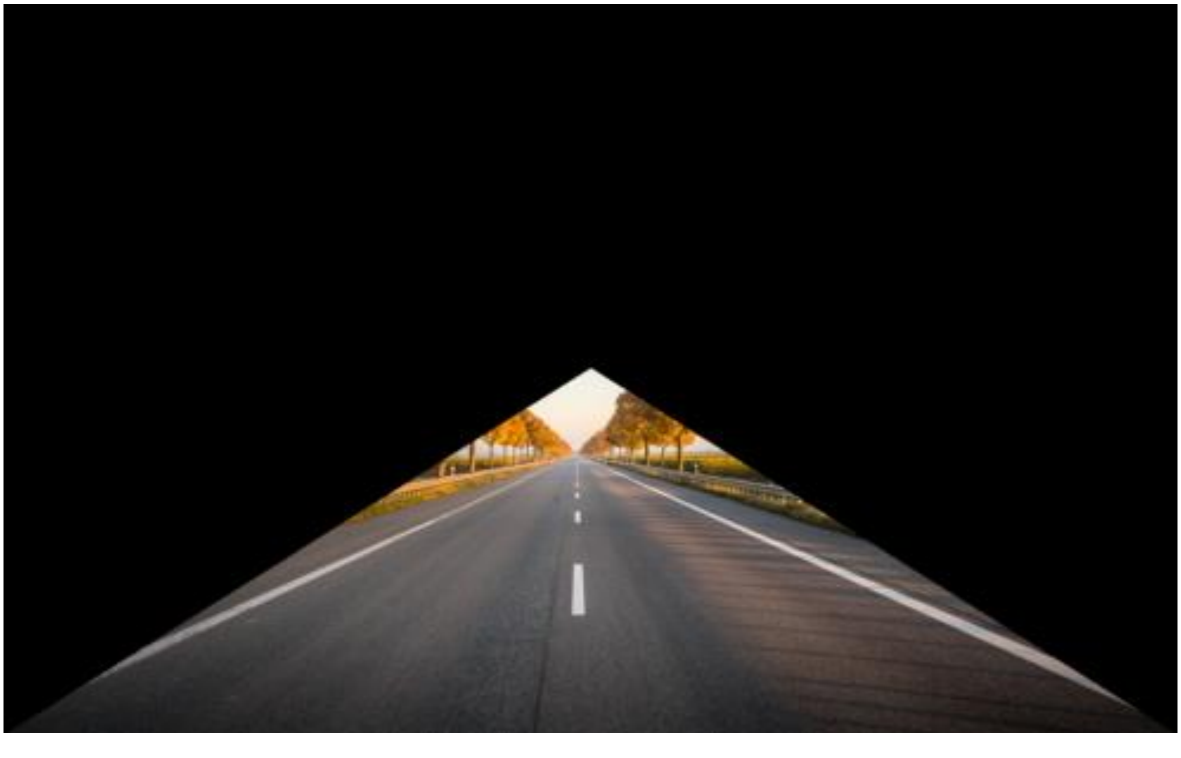
For detecting the lanes in the taken picture we need different types of theorem. Those theorems are applied in the code of Matlab to reach the desired output.

2.2.1 Region of Interest:

In the taken picture as given below as example we can see that the camera takes a wide angle of the front scenario of the car. But for lane detection we only need the closed scenario and the road. So for this case we will take the only those by defining them as the region of interest. We will do different on the region of interest to find the lane and draw them.

The main image:

The Region of Interest:



2.2.2 Canny Edge Detector

This is an edge detection operator that uses a multi-stage algorithm to detect the edges in images. *John F. Canny* has developed this algorithm. He is also the inventor of the theory explaining why the edge detection technique should work.

The Canny edge detector [7] works in 5 simple steps:

1. To smooth the image removing the noise using *Gaussian Filter.*
2. Finding out the intensity gradient of the image.
3. To get rid of spurious response to edge detection we need to apply gradient magnitude thresholding or lower bound cut-off suppression.
4. Use double threshold to determine the potential edges.
5. Draw edges by hysteresis.

Gaussian Filter:

The equation for a Gaussian filter kernel of size (2k+1) * (2k+1) is given by:

$$H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i-(k+1))^2 + (j-(k+1))^2}{2\sigma^2}\right); 1 \le i, j \le (2k+1)$$

Intensity Gradient of the image:

The gradient and the direction can be determined:

$$\mathbf{G} = \sqrt{\mathbf{G}_x{}^2 + \mathbf{G}_y{}^2}$$

$$\mathbf{\Theta} = \operatorname{atan2}(\mathbf{G}_y, \mathbf{G}_x),$$

Where,

G= gradient

Θ= direction

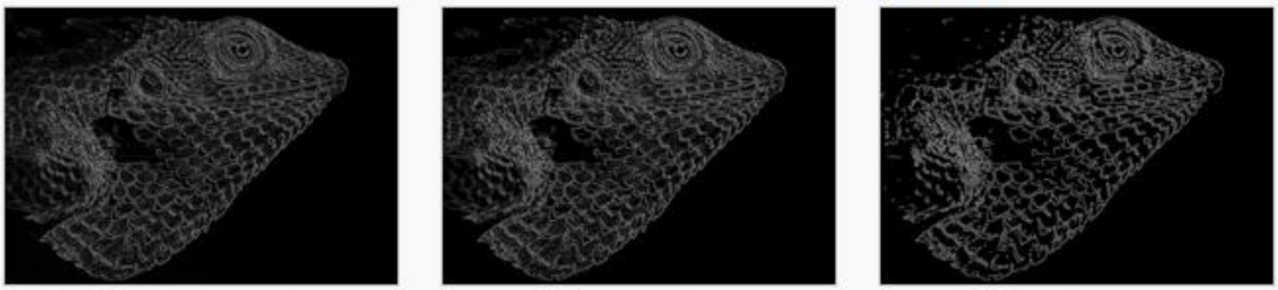
G_x= horizontal direction

G_y=vertical direction

The original image

Image has been reduced to grayscale, and a 5x5 Gaussian filter with σ=1.4 has been applied

The intensity gradient of the previous image. The edges of the image have been handled by replicating.



Non-maximum suppression applied to the previous image.

Double thresholding applied to the previous image. Weak pixels are those with a gradient value between 0.1 and 0.3. Strong pixels have a gradient value greater than 0.3

Hysteresis applied to the previous image

2.2.3 Hough Line Transform

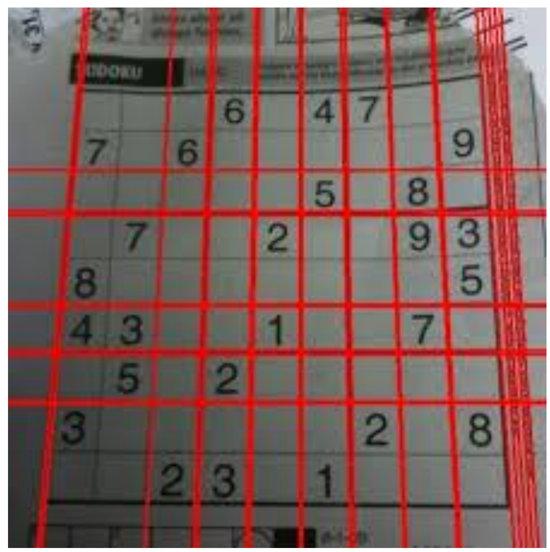
In image analysis, computer vision and digital image processing [8] this Hough line transform technique is used. The purpose of the technique is to find imperfect instance of objects within certain class of shapes by a voting procedure. This voting procedure is carried out in a parameter space, from which object candidates are obtained as local maxima in a so-called accumulator space that is explicitly constructed by the algorithm for computing the Hough line transform. *Richard Duda* and *Peter Hart* are the inventors of this algorithm. At first it was called ‘generalized Hough transform’ [9].

There are several arguments to do the Hough Line Transform in Matlab. Those are given below:

- Image: A gray scale image.
- Lines: A vector that will store the parameters of the detected lines.
- Rho: The resolution of the parameter r in pixels.
- Theta: The resolution of the parameter Θ in radians.
- Threshold: The minimum number of intersections to detect the line.
- MinLineLength: The minimum number of points that can form a line.
- MaxLineGap: The maximum gap between two point to be considered in the same line.

The main image:

Image after Hough Line Transform:

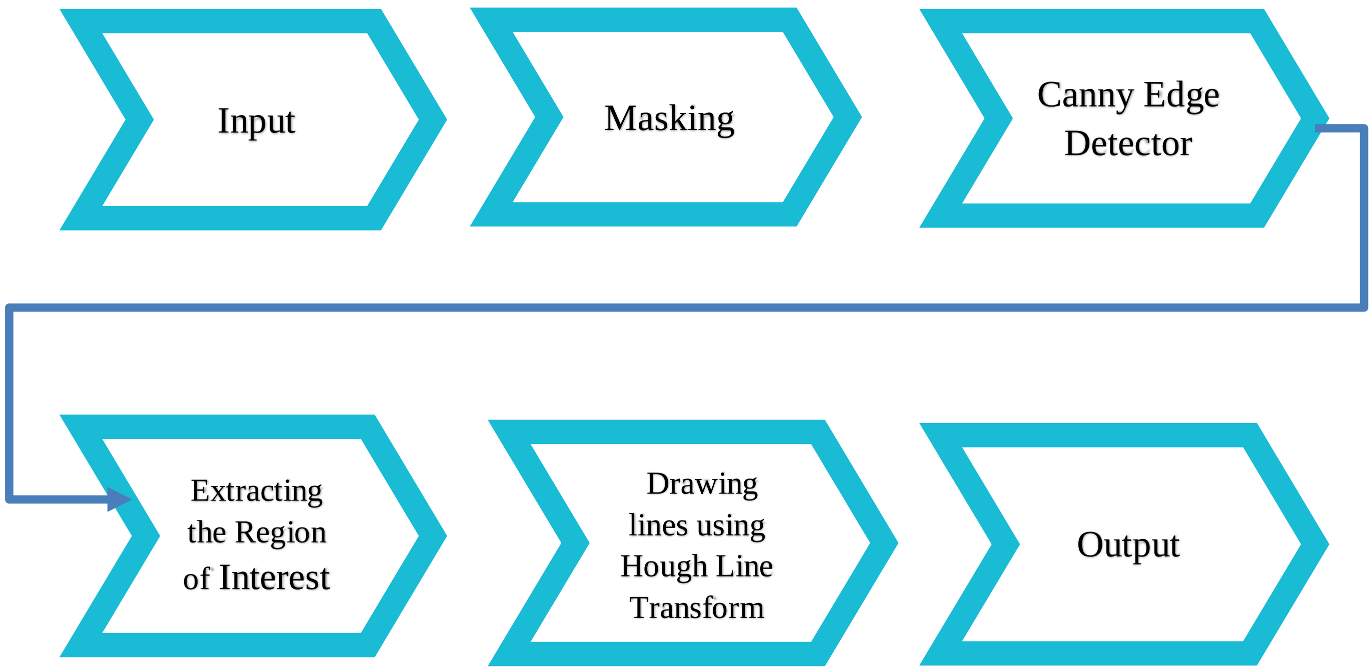


2.3 Process

2.3.1 Explanation:

In this process we took an image from the live video footage taken from the front camera of the car. Then we will try to process the image with the help of matlab. First of all, we will mask the image. This means we will check the color contrast and change it accordingly for the next steps so that the image could be observed without any fault. Then we will use Canny Edge Detector algorithm to find out the edges in that picture. Then we will take only that part of the image where the lanes are mainly. We will take the region of interest from the canny image we got from the last algorithm. Then we will draw lines on a blank image using Hough Line Transform algorithm from the cropped canny edge image. After drawing the lined we will overlap the image in the main image with some weighted value. Which will take the lane from the lane image and put it on the main image. From this we will get the image with lane detected which is needed for the further researches we have done.

2.3.2 Flowchart:



2.3.3 Code:

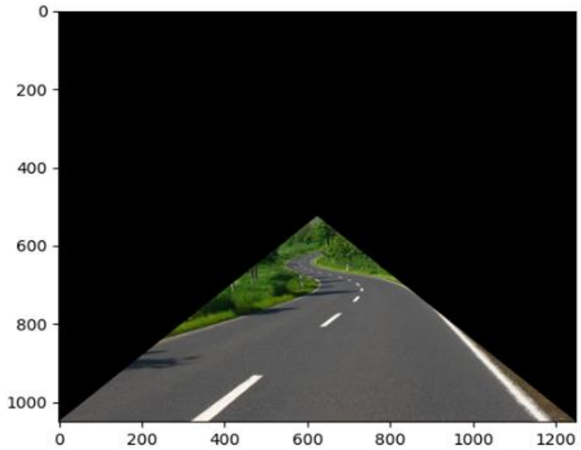
```
import matplotlib.pylab as plt

import cv2

import numpy as np


def region_of_interest(img, vertices):

    mask = np.zeros_like(img)

    match_mask_color = 255

    cv2.fillPoly(mask, vertices, match_mask_color)

    masked_image = cv2.bitwise_and(img, mask)

    return masked_image


def drow_the_lines(image, lines):

    image = np.copy(image)

    blank_image = np.zeros((image.shape[0], image.shape[1], 3), dtype = np.uint8)


    for line in lines:

        for x1, y1, x2, y2 in line:

            cv2.line(blank_image, (x1,y1), (x2,y2), (255,0,0), thickness=5)

    image = cv2.addWeighted(image, 0.8, blank_image, 1, 0.0)

    return image


image = cv2.imread('road.jpg')
```

```
image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)


print(image.shape)
height = image.shape[0]
width = image.shape[1]
region_of_interest_vertices = [
    (0, height),
    (width/1.5, height/1.5),
    (width, height)]
gray_image = cv2.cvtColor(image, cv2.COLOR_RGB2GRAY)
canny_image = cv2.Canny(gray_image, 100 , 200)
cropped_image = region_of_interest(canny_image,
                np.array([region_of_interest_vertices], np.int32),)
lines = cv2.HoughLinesP(cropped_image, rho=6, theta=np.pi/60, threshold=160,
lines=np.array([]), minLineLength=40, maxLineGap=25)
image_with_lines = drow_the_lines(image, lines)


plt.imshow(image_with_lines)
plt.show()
```

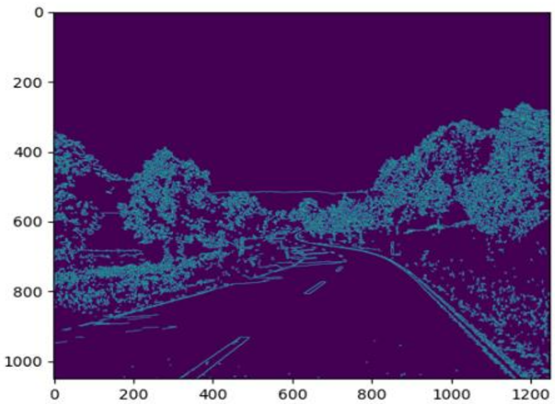
2.3.4 Images:

Input Image:

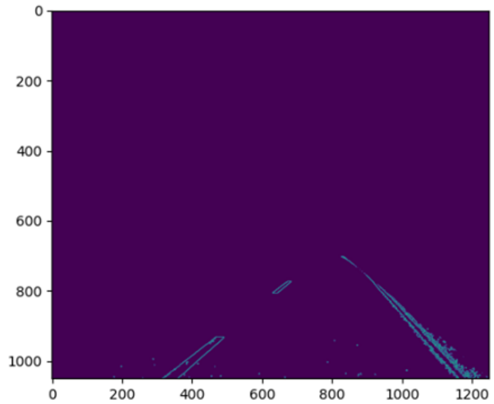
Region of Interest:



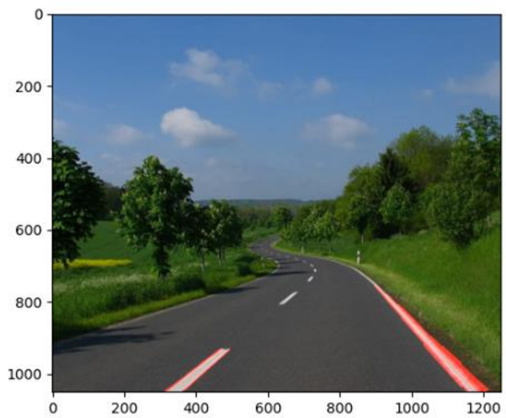
Canny Edge Detection:



Canny Edge Region of interest:



Lines drawn using Hough Line Transform:



CHAPTER 3

GNSS Sensors

3.1 Introduction

Tracking loops are used by global navigation satellite system (GNSS) receivers to latch onto GNSS signals. A global navigation satellite system is a satellite navigation system that has global coverage (GNSS). The Global Positioning System (GPS) of the United States, Russia's Global Navigation Satellite System (GLONASS), China's BeiDou Navigation Satellite System (BDS) [10], and the European Union's Galileo [11] are all fully functioning GNSSs as of September 2020. The Quasi-Zenith Satellite System (QZSS) is a (US) GPS satellite-based augmentation system designed to improve GPS accuracy, with satellite navigation independent of GPS expected to be operational by 2023. [12] In the long run, the Indian Regional Navigation Satellite System (IRNSS) intends to extend to a global version. [13]

A satellite constellation of 18–30 medium Earth orbit (MEO) satellites scattered over many orbital planes provides global coverage for each system. The exact structures differ, but they all have orbital inclinations of more than 50 degrees and orbital periods of around twelve hours (at an altitude of about 20,000 kilometres or 12,000 miles).

3.2 Classification

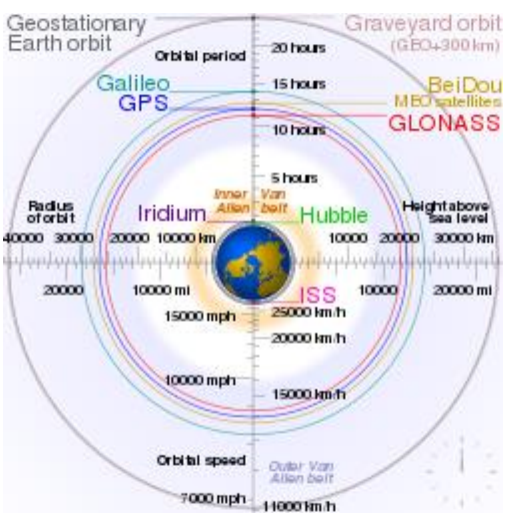
The following are the classifications for GNSS schemes that have improved accuracy and legitimacy control for civil navigation: [14]

• GNSS-1: is a first-generation satellite navigation system that combines existing satellite navigation systems (GPS and GLONASS) with Satellite Based Augmentation Systems (SBAS) or Ground Based Augmentation Systems (GBAS) (GBAS). [14]The Wide Area Augmentation System (WAAS) in the United States, the European Geostationary Navigation Overlay Service (EGNOS) in Europe, and the Multi-Functional Satellite Augmentation System in Japan are the satellite-based components (MSAS). Systems like the Local Area Augmentation System have ground-based augmentation (LAAS). [14]

• GNSS-2: The European Galileo positioning system is an example of the second generation of systems that separately have a complete civilian satellite navigation system. [14] The accuracy and integrity control required for civil navigation, including aircraft, will be provided by these systems. Initially, only Upper L Band frequency sets were used in this method (L1 for GPS, E1 for Galileo, G1 for GLONASS). Lower L-Band frequency sets (L2 and L5 for GPS, E5a and E5b for Galileo, G3 for GLONASS) have been enabled for civilian use in recent years, offering better aggregate precision and less signal reflection issues. [15] [16]

3.3 Global navigation satellite systems

In order of First Launch year:



Comparison of orbit sizes for the GPS, GLONASS, Galileo, BeiDou-2, and Iridium constellations, as well as the International Space Station, Hubble Space Telescope, and geostationary orbit.

3.4.1 Application

Many applications use Global Navigation Satellite System (GNSS) receivers that use the GPS, GLONASS, Galileo, or BeiDou systems. The first location recognition devices were created in the 20th century, mostly to aid military forces in finding their way, but civilian implementations quickly followed.

- GNSS receivers are available as factory-installed or aftermarket options for automobiles. Moving maps and information about position, speed, route, and nearby streets and points of interest are frequently displayed on units.

A GPS receiver in civilian automobile use.

- For en-route navigation, air navigation systems typically have a moving map display and are also attached to the autopilot. Glass cockpits and cockpit-mounted GNSS receivers are becoming more popular in general aviation aircraft of all sizes, with systems like WAAS or LAAS used to improve precision. Many are certified for instrument flight rules navigation, and others, including the Joint precision approach and landing system, can also be used for final approach and landing operations. Glider pilots use GNSS Flight Recorders to register GNSS data confirming their arrival at turn points in gliding contests, as well as for information to help in cross-country soaring decision making.

- GNSS can be used by boats and ships to cross any of the world's waterways, rivers, and oceans. Maritime GNSS units have features that are helpful on the water, such as "man overboard" (MOB) functions, which allow for the immediate marking of a person who has fallen overboard, making rescue operations easier. The NMEA 0183 interface can be used to attach GNSS to the ship's self-steering gear and chartplotters. By allowing AIS, GNSS can also increase the protection of shipping traffic.

GPS unit showing basic way point and tracking information as typically required for outdoor sport and recreational use.

- In manufacturing, logging, and precision agriculture, heavy machinery may use GNSS. Construction machinery blades and buckets are automatically operated by GNSS-based computer guidance systems. Agricultural equipment can use GNSS to automatically steer or as a visual aid for the driver on a tablet. This is helpful for traffic management, row crop activities, and spraying. Harvesters who use yield monitors will use GNSS to build a yield map of the paddock they're working on.

- Bicycle with GPS (left) and cyclocomputer :
  GNSS is often used by cyclists in cycling and touring. GNSS routing helps cyclists to plan their route ahead of time and follow it without stopping to consult different maps. This route can have quieter, smaller streets. GNSS receivers built for cycling can include 'street-aware' mapping features or be geared toward tracking the cyclist's progress along the road. This information can be analyzed during the ride to help riders schedule their training or competitions, or it can be submitted to web sites that enable riders to access and compare their journeys. [17]
- Hikers, hikers, and even ordinary pedestrians in urban and rural areas may use GNSS to assess their position, either with or without the use of separate maps. When climbers or hikers get injured or stranded in remote locations, the ability of GNSS to have a specific location can significantly improve the odds of rescue (if they have a means of communication with rescue workers).
- GNSS equipment for the visually impaired is available.
- The Global Navigation Satellite System (GNSS) is a navigational instrument used by spacecraft. Without a ground tracking station, a spacecraft with a GNSS receiver can determine its exact orbit. As a result, automated spacecraft navigation, formation flying, and autonomous rendezvous are now possible. Only if the receiver can acquire and detect the much weaker (15 - 20 dB) GNSS side-lobe signals is it possible to use GNSS in MEO, GEO, HEO, and extremely elliptical orbits. COTS receivers cannot be used in space due to design constraints and the radiation environment. GNSS is easier to use than low-earth-orbit satellites. Orbcomm's constellation, for example, uses GPS receivers on

both of its satellites. [18] China has successfully conducted tests using low-cost COTS single-frequency GPS receivers mounted on the Yaogan-30 (YG30; LEO) series and Fengyun-3C (FY3C; SSO) satellites. Using several systems at the same time helps with the polar orbits of FY3C by allowing more GNSS satellites to be visible.[19]

- Geographic information systems (GIS) and mapping — Most mapping-grade GNSS receivers use only the L1 frequency carrier wave data, but they have a precise crystal oscillator that reduces errors caused by receiver clock jitter. For a differential GNSS signal received using a separate radio receiver, positional errors of the order of one meter or less may be achieved in real-time. These receivers can achieve positional errors of up to 10 centimeters by storing carrier phase measurements and differentially post-processing the data.
- Several projects, including OpenStreetMap and TierraWiki, allow users to create maps collaboratively, much like a wiki, using consumer-grade GPS receivers.
- Geophysics and geology — Differential GNSS can be used to make high-precision measurements of crustal strain by determining the relative displacement between GNSS sensors. To detect strain and ground displacement, several stations may be placed around a dynamically deforming region (such as a volcano or fault zone). The origin of the deformation, such as a dike or sill under the surface of an active volcano, can then be deduced from these measurements.
- Archaeology — Archaeologists typically create a three-dimensional map of a site as they excavate it, detailing where each artifact is discovered.[20]
- Surveying — GNSS receivers with survey-grade accuracy can be used to position survey markers, homes, and road development. Both the L1 and L2 GPS frequencies are used for these systems. About the fact that the L2 code data is encrypted, the carrier wave of the signal allows for the correction of any ionospheric errors. These dual-frequency GPS receivers normally cost $10,000 or more, but when used in carrier phase differential GPS mode, they may have positioning errors of one centimetre or less.
- Survey-grade A limited number of major players in the GNSS receiver industry specialize in the design of complex dual-frequency GNSS receivers capable of accurate carrier phase monitoring for all or most available signals in order to get relative

positioning precision down to cm-level values demanded by these applications. Javad, Leica, NovAtel, Septentrio, Topcon, and Trimble are the most well-known firms.

3.4.2 Other Uses

- Military precision-guided projectiles – GNSS is used to direct a variety of munitions, including JDAM bombs and the Excalibur 155 mm artillery gun.
- Precise time reference – GNSS is used as a source of accurate time for many applications that must be precisely synchronized. Time code generators and Network Time Protocol (NTP) time servers will use GNSS as a reference clock. Sensors may use GNSS as a precise time source (for seismology or other tracking applications). This precise timing is often used in time-division multiple access (TDMA) communications networks to synchronize RF generating devices, network equipment, and multiplexers.
- Mobile satellite communications – A directional antenna (usually a "dish") is pointed at a satellite in satellite communications systems. A moving ship or train, for example, would point its antenna depending on its current position. A GNSS receiver is normally included in modern antenna controllers to provide this information.
- Emergency and location-based services – Emergency responders may use GNSS functionality to find mobile phones. E911 emergency response law in the United States mandates the right to identify a cell phone. However, such a scheme does not exist in every country. For compatible electronics, GNSS is less reliant on telephone network topology than radiolocation. Assisted GPS lowers the cell phone's power consumption while increasing location accuracy. The physical location of a phone may also be used to offer location-based services, such as ads or other information unique to a specific location.
    - Location-based games – The availability of hand-held GNSS receivers has led to games like geocaching, which entails traveling to a given longitude and latitude to look for items concealed by other geocachers using a hand-held GNSS device.
    - Marketing – Some market research firms have merged GIS programs and survey-driven research to assist businesses in deciding when to launch new outlets and

targeting their advertising based on road use trends and suburban zone socio-demographic characteristics.

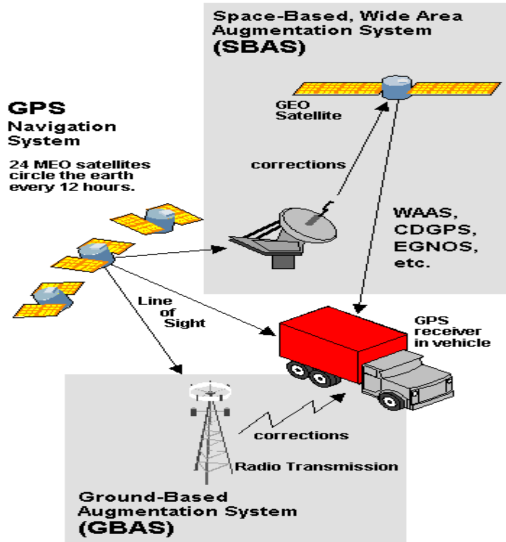
- Aircraft passengers – Most airlines encourage passengers to use GNSS units on their flights, with the exception of landing and takeoff, where all electronic devices are prohibited. Despite the fact that customer GNSS receivers pose a low risk of interference, some airlines prohibit the use of hand-held receivers while flying. Other airlines incorporate aircraft monitoring into the seat-back television entertainment system, making it accessible to all travelers at takeoff and landing.[21]
- Heading information – Even though it was not planned for this, the GNSS can be used to specify heading detail. A "GNSS compass" detects the phase difference in the carrier signal from a specific GNSS satellite using a pair of antennas separated by around 50 cm. [number six] The direction of the two antennas can be calculated using the satellite's location, the antenna's position, and the phase difference. Three antennas in a triangle are used in more expensive GNSS compass systems to get three different readings with respect to each satellite. A GNSS compass, unlike a magnetic compass, is not affected by magnetic declination and does not require periodic reset like a gyrocompass. It is, however, subject to multipath effects.
- GPS tracking systems use the Global Navigation Satellite System (GNSS) to determine the location of a car, human, pet, or freight, and to report the position at regular intervals to establish a log of movements. The information may be stored on the device itself or transmitted to a remote computer via radio or cellular modem. Some programs enable users to access the location in real time from the Internet using a web browser.
    - As a condition of release, GPS anklets are worn to monitor the whereabouts of convicted sex criminals. For either $5 to $10 a day, law enforcement officers may review suspects' regular movements. For GPS monitoring of suspects, real-time, or instant, tracking is considered too expensive.[22]
- Apps may be activated or disabled depending on their position using geo-fences.
- GNSS road pricing schemes use data from GNSS sensors within vehicles to tax road users. Advocates contend that using GNSS for road pricing allows for measures like tolling by distance on urban highways, as well as a variety of other uses of parking,

insurance, and automotive emissions. GNSS, according to critics, could amount to an infringement of people's privacy.

- Weather prediction – Using advanced GNSS receivers in orbital satellites to measure atmospheric bending of GNSS satellite signals, atmospheric conditions such as air mass, temperature, precipitation, and electron density can be determined. The Constellation of Observing System for Meteorology, Ionosphere, and Climate COSMIC, a constellation of six microsatellites launched in April 2006, has been shown to increase the accuracy of weather forecast models.
- Photographic geocoding – When GNSS position data is combined with images taken with a (typically digital) camera, the photographs can be seen on a map[23] or the positions where they were taken can be looked up in a gazetteer. By inserting a GNSS system into the camera and embedding co-ordinates as Exif metadata, it is possible to automatically annotate images with the position they represent. Alternatively, image timestamps can be compared to a GNSS track log.[24][25]
- Skydiving – A GNSS is used for most commercial drop zones to help the pilot "spot" the plane to the right direction so that all skydivers on the load can fly their canopies back to the landing field..
- Wireless networking – Wardriving is a method of mapping and downloading the actual or precise location of a wireless network. It determines the direction using data from the wireless adapter's signal strength and GPS. Kismet is a popular wardriving application for Linux..
- Wreck diving – Wreck diving is one of the most common types of scuba diving. To find the target shipwreck on the ocean floor, GPS is used to navigate to an estimated spot, and then an echosounder is used to find the shipwreck.
- Social networking – A growing number of companies are selling cellular phones with GPS technology, which enable users to locate friends on custom-created maps and receive warnings when the group enters a pre-determined range. Not only do all of these phones have social networking capabilities, but they also have standard GPS navigation functionality including audible voice commands for in-car navigation.

3.5 Augmentation

The Wide Area Augmentation System, the European Geostationary Navigation Overlay Service, the Multi-functional Satellite Augmentation System, Differential GPS, and GPS-aided GEO augmented navigation are examples of GNSS augmentation systems.



3.6 The role of GNSS in driverless cars

Large visual map databases are being developed, which, when combined with cameras, radars, and lidars on the vehicle and interpreted by artificial intelligence (AI) algorithms, allow the driverless car to be steered in a manner similar to how humans drive. The vehicle's pattern recognition processing helps it to "interpret" street signs and identify landmarks, allowing it to register its location on the map.

This is how a person drives in his or her hometown, where they are still aware of their orientation and do not need the use of GNSS. With access to massive map databases through local storage or a network link, the AI processing "brain" will still be in its familiar home area, constantly knowing its own location and properly organized for navigation.

So, will GNSS be obsolete in the future automobile? Very likely not.

To begin with, no single form of navigation is foolproof, and today, we use GNSS to navigate our vehicles. It's a low-cost, high-accuracy method of deciding location in real time, and it's getting better with the addition of inertial navigation sensors to tackle situations where GNSS is intermittently unavailable.

Second, not only the vehicle itself, but also those outside the car, need positioning information for navigation. Uber and Lyft, as well as ride-sharing, usage-based insurance, dynamic toll pricing, and parking applications, all depend on understanding where the car is at all times. By supplying position coordinates, GNSS provides adequate precision for both of these apps.Therefore, a GNSS receiver will most likely remain in the car.

Chapter -4

CARLA

4.1 Introduction to CARLA

Mainly researches in self-driving vehicles is obstructed by [26]

- Cost to build the entire system
- Training the system to perfection, at least to make the efficiency better.
- Management of the entire system

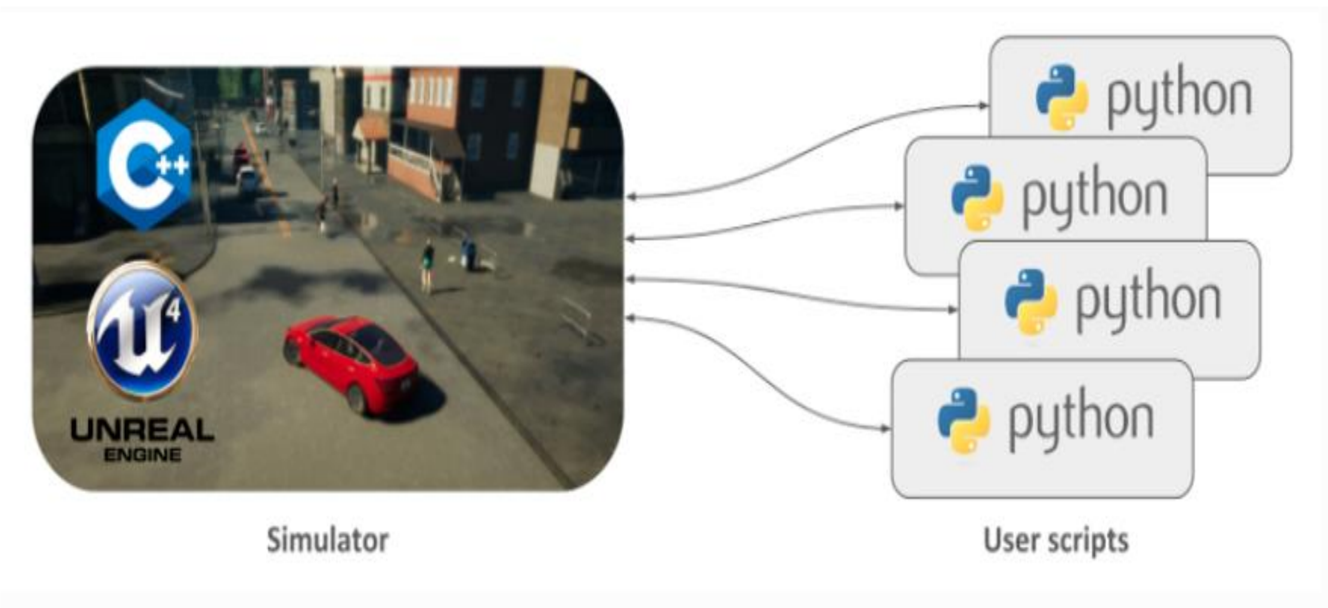
The proper build up to the mechanism of this self-driving vehicle requires enough investment in the following criteria:

- Financial Investment
- Manpower
- Expertise

So the alternative to this that is thought to be is to train and design the entire system and to run a simulation to see the outcome.

It is also necessary for system verification, since some scenarios are too dangerous to be staged in the physical world (e.g., a child running onto the road ahead of the car). Simulation has been used for training driving models since the early days of autonomous driving research [27].

CARLA is an open source photorealistic simulator [28] developed to train, validate and test autonomous driving algorithms. It is written in C++ and its driving scenarios are based on Unreal Engine. It provides digital assets and complete control on actors on the map, environmental conditions control, a sensor suite, maps generation, a flexible API and a server-client based communication. In addition to CARLA Simulator, that embeds all the control logic, the rendering, the physics and all the actor properties, CARLA offers a Python API module. So the server is the Simulator and the client-server communication is controlled through the Python API. [29]



Source: www. Carla.org

Most of the aspects of the simulation are accessible from the Python API. With Python scripts it is possible to retrieve raw data coming from CARLA sensors attached to the ego vehicle, process them, compute all the parameters needed by the controller and send to CARLA Simulator the controls of throttle, brake and steering.

Each Python script from the client side can be logically divided into two different parts:

- Configuration of the simulation and of the actors:

Before starting the control algorithm, the connection with the server and all the settings of the simulation and the actors has to be done. Here information on the world can be retrieved, actors can be spawned at arbitrary locations and orientations, sensors can be attached to the ego vehicle and other actors can be created, spawned or destroyed.

- Client-Server synchronized communication: The control algorithm is contained in this part, where the proper simulation is started. The sensor(s) attached to the vehicle produce raw data and the client subscribe to the sensor stream by providing a callback function that is called each time a new data is generated by the sensor. This callback function is the one that stores the images in a queue accessed by the control algorithm to return the controls to the vehicle. At the end of the simulation the client disconnects.

We use CARLA to study the performance of three approaches to autonomous driving. The first is a classic modular pipeline that comprises a vision-based perception module, a rule-based planner, and a maneuver controller. The second is a deep network that maps sensory input to driving commands, trained end-to-end via imitation learning. The third is also a deep network, trained end-to-end via reinforcement learning. We use CARLA to stage controlled goal-directed navigation scenarios of increasing difficulty. We manipulate the complexity of the route that must be traversed, the presence of traffic, and the environmental conditions. [26]

4.2 The Engine

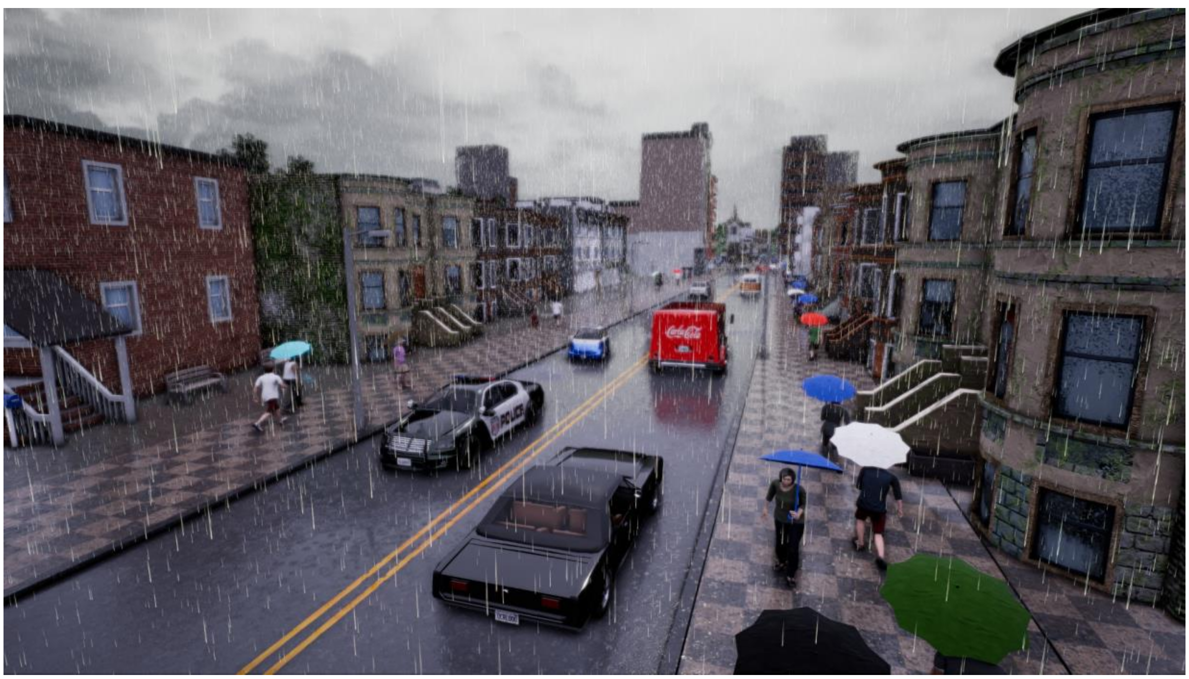
CARLA was built to make the works easier through the simulation processes. Now, it is implemented as an open-source layer over Unreal Engine 4 (UE4) [27], enabling future extensions by the community. The engine provides state-of-the-art rendering quality, realistic physics, basic NPC logic, and an ecosystem of interoperable plugins.

During the simulation, Carla simulates in a world which is dynamic in nature, contains a simple interface to connect the person that is control with that particular augmented reality
CARLA is designed as a server-client System [26], where the server runs the simulation and renders the scene. The client API is implemented in Python and is responsible for the interaction between the autonomous agent and the server via sockets. The client sends commands and meta-commands to the server and receives sensor readings in return. Commands control the vehicle and include steering, accelerating, and braking. Meta commands control the behavior of the server and are used for resetting the simulation, changing the properties of the environment, and modifying the sensor suite.

4.3 The Environment

The weather of this virtual reality simulation platform can be manipulated of the following patterns

Bright sunny day



Raining in the day

During sunset

A period after the rain

The setup of the environment is built on 3D models of static objects such as buildings, vegetation, traffic signs, and infrastructure, as well as dynamic objects such as vehicles and pedestrians.
All models are carefully designed to reconcile visual quality and rendering speed: we use low-weight geometric models and textures, but maintain visual realism by carefully crafting the materials and making use of variable level of detail [26].

Pedestrians navigate the streets according to a town-specific navigation map, which conveys a location-based cost. This cost is designed to encourage pedestrians to walk along sidewalks and marked road crossings, but allows them to cross roads at any point. Pedestrians wander around town in accordance with this map, avoiding each other and trying to avoid vehicles. If a car collides with a pedestrian, the pedestrian is deleted from the simulation and a new pedestrian is spawned at a different location after a brief time interval.

4.4 Sensors

We have taken the help of sensors which worked in the augmented reality simulation process.

Autonomous vehicles do take the help of cameras. By equipping the vehicle with cameras of 360 degrees there can be an overview of the entire thing found. Unfortunately, these camera sensors are still far from perfect. Poor weather conditions such as rain, fog, or snow can prevent cameras from clearly seeing the obstacles in the roadway, which can increase the likelihood of accidents. Additionally, there are often situations where the images from the cameras simply aren't good enough for a computer to make a good decision about what the car should do. For example, in situations where the colors of objects are very similar to the background or the contrast between them is low, the driving algorithms can fail. [30] Cameras can be of following types in Carla simulator:

- Depth Camera
- RGB Camera
- Semantic Segmentation Camera
- DVS Camera

The sensors that are associated with CARLA are:

- **Radar Sensor**
  Radar (Radio Detection and Ranging) sensors make up a crucial contribution to the overall function of autonomous driving: they send out radio waves that detect objects and gauge their distance and speed in relation to the vehicle in real time.
- **Lidar**
  Lidar (Light Detection and Ranging) sensors work similar to radar systems, with the only difference being that they use lasers instead of radio waves. Apart from measuring the distances to various objects on the road, LIDAR allows creating 3D images of the detected objects and mapping the surroundings. Moreover, LIDAR can be configured to create a full 360-degree map around the vehicle rather than relying on a narrow field of view. These two advantages make autonomous vehicle manufacturers such as Google, Uber, and Toyota choose LIDAR systems.
- **IMU Sensor**
  An inertial measurement unit works by detecting linear acceleration using one or more accelerometers and rotational rate using one or more gyroscopes. Some also include a magnetometer which is commonly used as a heading reference. Typical configurations contain one accelerometer, gyro, and magnetometer per axis for each of the three principal axes: pitch, roll and yaw. [31]

- **GNSS Sensor**
  Global Navigation Satellite System (GNSS) receivers, using the GPS, GLONASS, Galileo or ... or Network Time Protocol (NTP) time servers. Sensors (for seismology or other monitoring application) can use GNSS as a precise time source.

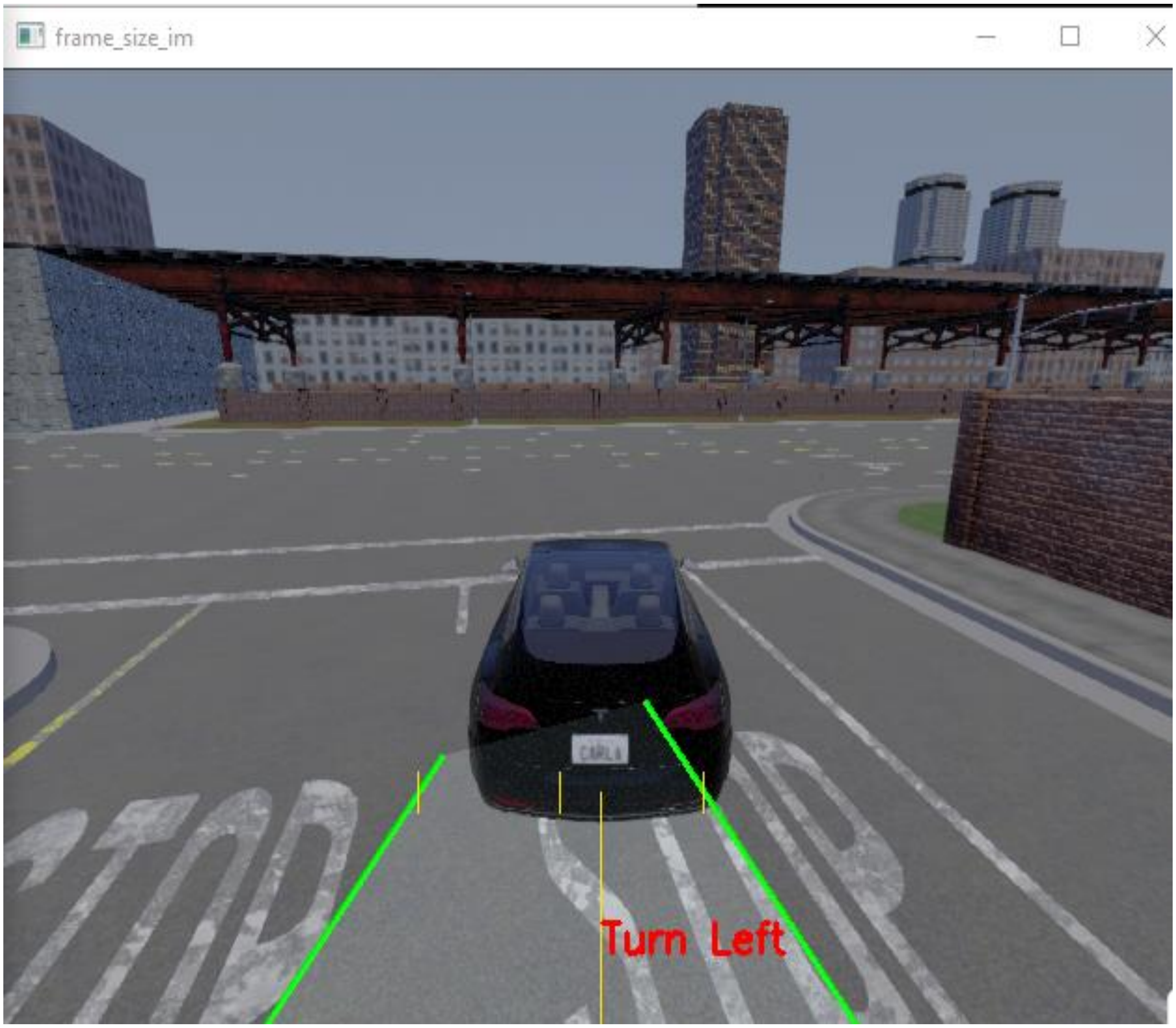
- **RSS Sensor**

  The RSS library implements a mathematical model for safety assurance. It receives sensor information, and provides restrictions to the controllers of a vehicle. [32]

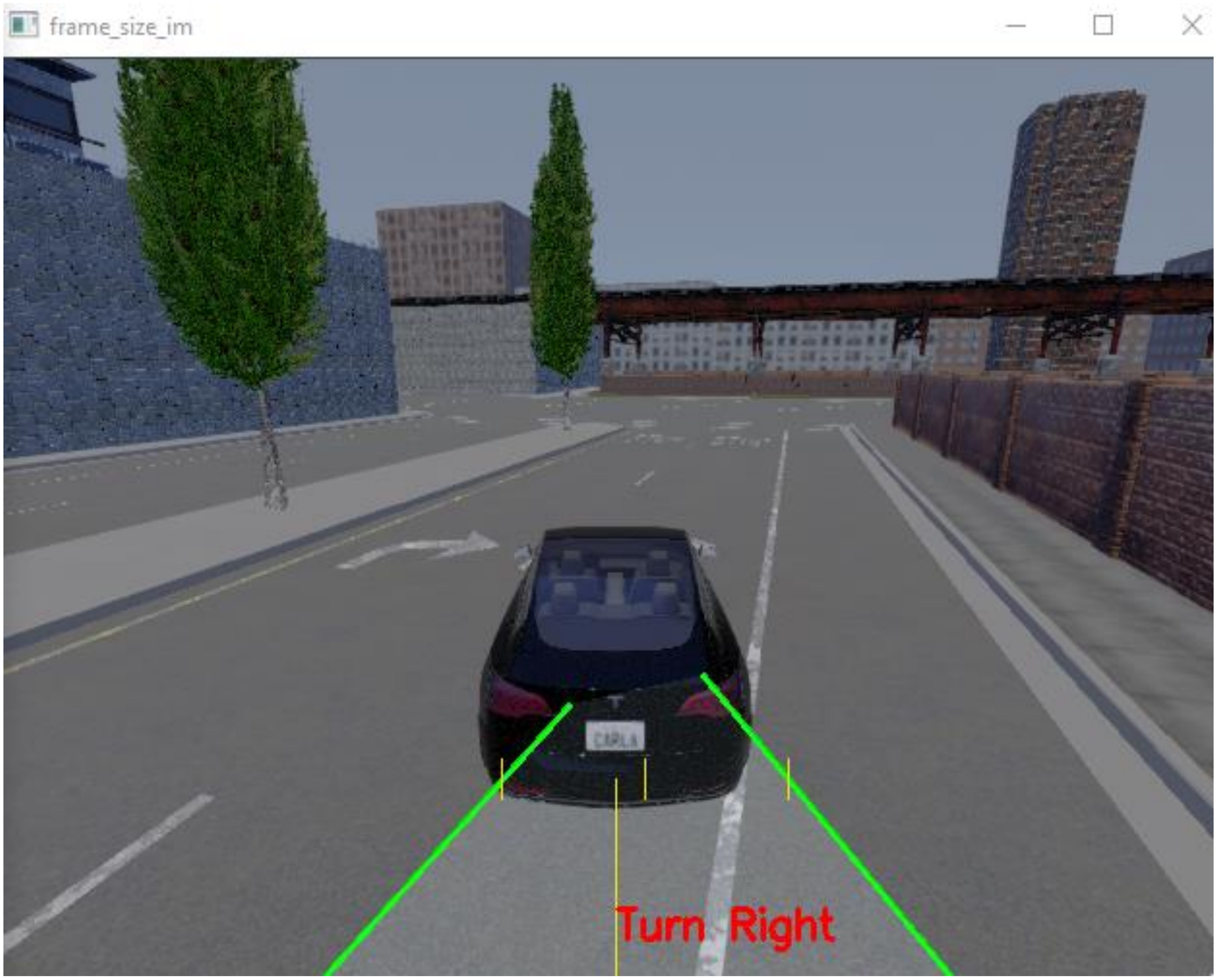
Chapter -5

CARLA Simulation

Here, in the figure, the yellow line is the main orientation of the car. And the three yellow small lines & the green lines represent the car positioning based on the sensor value previously given in Carla. Based on the middle small yellow line and the yellow line for the car orientation we determine the cars orientation. In the figure, we can see that the difference between the virtual center and the car's center is zero. So, the output is showing the car is at the center of its lane.



In the figure it is shown that the difference between the virtual center and the cars center is positive. So the output is showing that the car is a little bit left from the center of the lane of its lane.



In the figure it is shown that the difference between the virtual center and the cars center is negative. So the output is showing that the car is a little bit right from the center of the lane of its lane.

Chapter -6

Future Work

From our work perspective, driving assistance is more applicable than the entire self-driving car and realistic considering third world countries like Bangladesh. As the work that has been done till now is mainly simulation based.

Now we are targeting to proceed our work in physical form. For more accuracy, at first, we will try this in virtual car with real life sensors. Collecting all the data from that we will debug our code accordingly for more accuracy and implement it in real cars with real time sensors. After this, we will go with our work for public use as up till now it was entirely experimental. We will collect feedback from the beta testers and will try to improve the driving assistance system accordingly.

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