Self-Driving Car: A Step to the Future of Mobility

A Thesis

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Of

BRAC University

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Declaration

We, hereby declare that this thesis is based on robotics application we have implemented. Materials of work from research conducted by others are mentioned in references.

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ABSTRACT

Self-driving car also known as a driverless car is one of the most surprising technologies of twenty first century. In coming years, autonomous car would definitely take a large market in the developed countries and it will bring a revolutionary change in the street. It will help to reduce traffic, reduce pollutions, avoid maximum accidents, save time, conserve energy and provide better safety to human. All these points are quite common in our country. Moreover, during heavy traffic jam it will help the driver to relax from continuously monitoring the surroundings of the vehicle. Therefore, with mission and vision of eradicating these problems from our country, we focus on an autonomous car which may help us to save ourselves from the daily curse we have faced everyday on road. Moreover, it is high time we entered in the world of autonomous technologies.

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CHAPTER 1

Introduction

In the modern era, people are trying to focus on alternative system to do many of their tasks with less efforts and high precision. Many advanced intelligent systems have been developed to serve human in their daily life. If we can avoid some of our daily tasks and save our valuable time, we can put those minutes on other productive work. Moreover, in recent years, we have witnessed amazing progress in AI related field e.g. Self-driving Car. Mainly the vehicles are focused to be automated so that we can ride for a long distance without being tired. Another point is it can give us relief from continuously pushing accelerator, brake, clutch etc. In our research we are trying to build a four wheeler two seated vehicle which consists of many sensors such as obstacle sensor, GPS, compass along with camera to map the conditions of its surroundings on the road and help it to avoid collision. Also the vehicle will use Google maps Platform – Geo-location APIs to simultaneously localize and map the vehicle. For the measurement of the level of automation there are 5 levels in total starting from Level 0-No automation (fully controlled by the driver), Level 1-Driver Assistance (simple ADAS functions, such as steering control or acceleration), Level 2-Partial Automation (steering and acceleration can be controlled by the car, but the driver needs to be ready to take over) e.g. Tesla's Autopilot. Level 3-Conditional Automation (automation still requires the driver to be present, but is able to completely shift "safety-critical functions" to the vehicle, under certain traffic or environmental conditions). Level 4-High Automation which is considered to make the vehicle fully autonomous, up to some exceptional driving scenarios, Google's "Waymo" has been testing Level 4 autonomous vehicles in Arizona. Finally, Level 5-Complete Automation which represents a fully autonomous self-driving car [1]. In our research we are focusing on a Level 2 autonomous car. The whole system is divided into four parts-mechanical structure, sensor data acquisition, dynamic control and autonomous navigation. In this paper, we describe the entire system we have developed and various algorithmic improvements and solutions.

1.1 Motivation

An autonomous car is defined as a car without a driver which can sense its surrounding by using the built in sensors of its body. The benefits of autonomous car include increased safety, less infrastructure costs, reduced pollution etc. Moreover, a significant reduction of traffic collisions is also visible due to automated driving. Human drivers break the traffic rules in our country on a continual basis. As a result, traffic jam is a day to day problem in our daily life.

Therefore, an autonomous car can reduce the traffic jam by following traffic rules and relief us from the hectic life we lead in the road. Also, our vehicle is impelled by electric motors which use energy from the storage of rechargeable batteries. It will reduce environmental pollution by reducing the use of fuels and keep our country green. Besides, if a driver somehow gets ill while driving, the IOT based self - driving feature of this car will help the driver to reach the nearest hospital immediately. Moreover, deeply concerned about the road conditions of Bangladesh, the custom made chassis of this car will enhance comfort especially to the elder people and pregnant women.

CHAPTER 2

Literature Review

In this section, background of self-driving car is given along with the level of automation.

Self-driving car or autonomous car travels to their destination without any human operation as it uses a combination of sensors, radar, lidar, cameras, map and artificial intelligence. It’s a combination of technologies and automation where driver is eliminated or may have some limited control due to involvement of combined technologies and other used components. Before 1930s driverless cars were only the science fiction things but as digital computer developed then people dreamed about autonomous cars. Since 1920s autonomous cars are conducted through promising trails took place in 1950 and further development proceeded since then [2]. Beyond the pages of science fiction since our grandparent’s youth there is self-driving family car which will navigate the complex street of a city.

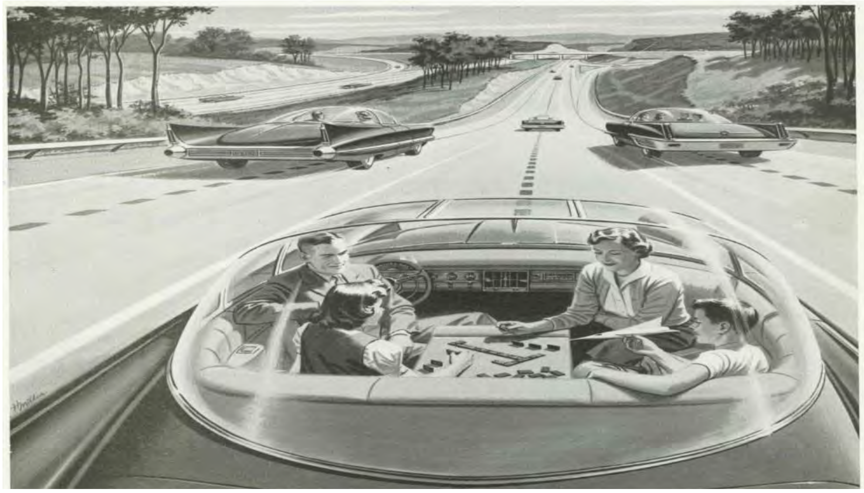


Figure: 2.1a Driverless car of the Future, advertisement for "America's Electric Light and Power Companies", Saturday Evening post, 1950s.

In figure.2.1a the picture is the advertisement of America's Electric Light and Power Company [6]. In 1980 and also in 1984 Carnegie Mellon University's Navlab and ALV projects also took a step toward automation of vehicles [2], [3]. BRAViA an automated vehicle that moved autonomously on a mixed traffic route [3]. In the 1980s German pioneer Ernst Dickmanns got a Mercedes van to drive autonomously hundreds of miles on highways [5].

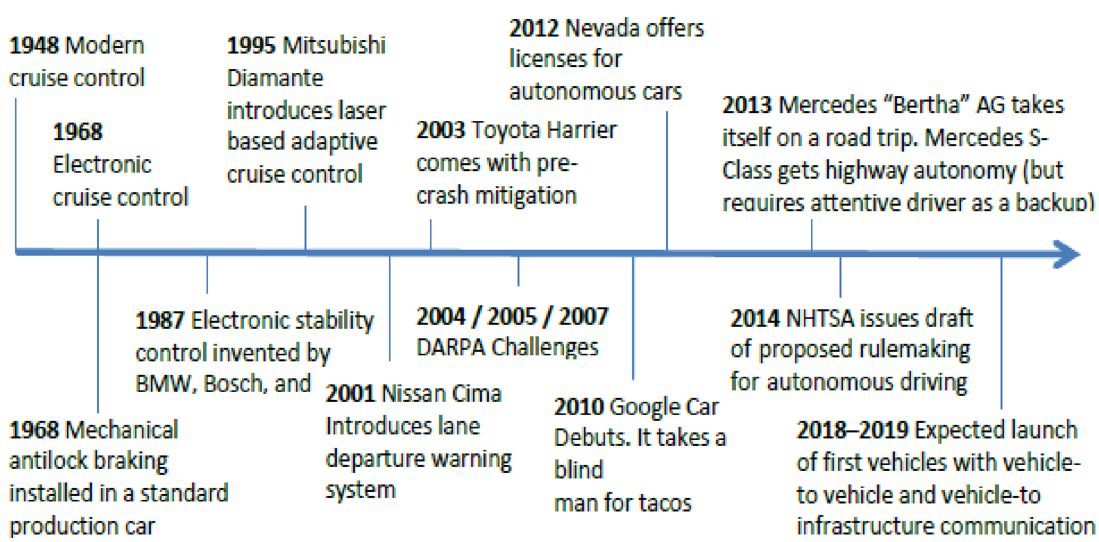


Fig: 2.1b Sixty five years of automotive baby steps (Ross,2014, p,62)

Figure: 2.1b shows the whole journey of autonomous car [9]. Another project is The Eureka PROMETHEUS one of the largest research program in history when it comes to autonomous driving vehicles. A number of driverless prototypes made by Mercedes-Benz and Ernst Dickman developed autonomous car using microprocessors, steering throttle and brakes were controlled through computer commands based on a real-time evaluation of image processing. Main target of this project was to avoid the collision. After so many years of study and research people made it possible to run a vehicle. Driverless cars are capable of steering autonomously, navigating, deciding, foreseeing and act smarter in critical situation. Most important thing is that there will be no human involvement. In the mid-2000, the Defense Advanced Research challenges (DARPA) where groups assembled to contend with autonomous car. 2009 is the year when Google began to contend with autonomous car. In 2009 Google invented self-driving car. After few years Google launched and tested some new features like removable steering wheel, acceleration pedal and brake pedal allow them to use these if needed [7]. Most inspiring project of self-driving car is Google autonomous car project "Waymo". It is so much interesting that it takes a blind man for tacos. It not only drives autonomously but also parked on its own. Heart of the system is a laser range-finder mounted on the roof of the car says Urmson who is the tech lead for the project [8]. This device is a Velodyne 64-beam laser which generated a 3D map of the environment [8]. It carries other sensors like radars, mounted on the front and rear bumper which help the car to see far enough to be able to deal with fast traffic on freeways. It used GPS, internal measurement unit, wheel encoder, rear view mirror for detect traffic lights.

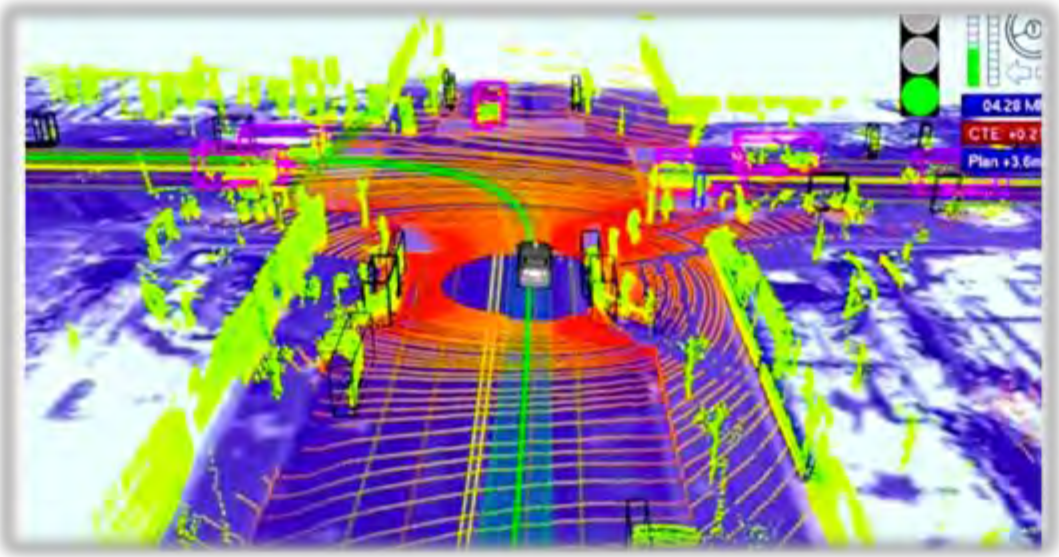


Fig: 2.1c Google's self-driving car uses lidar to create 3D image of the environment [9]

"Systematic literature review on user interface of autonomous cars" in this paper author said talk about some levels of automation which are [10]:

- No automation and much like a standard vehicle which contain automated warning systems or some secondary function [10].
- Driver can give up on one to two primary functions such as steering and braking for a limited period of time.

- Driver can give control to the vehicle for a certain period of time but driver's attention is needed to take the control back.
- Full automation of these automated vehicles.

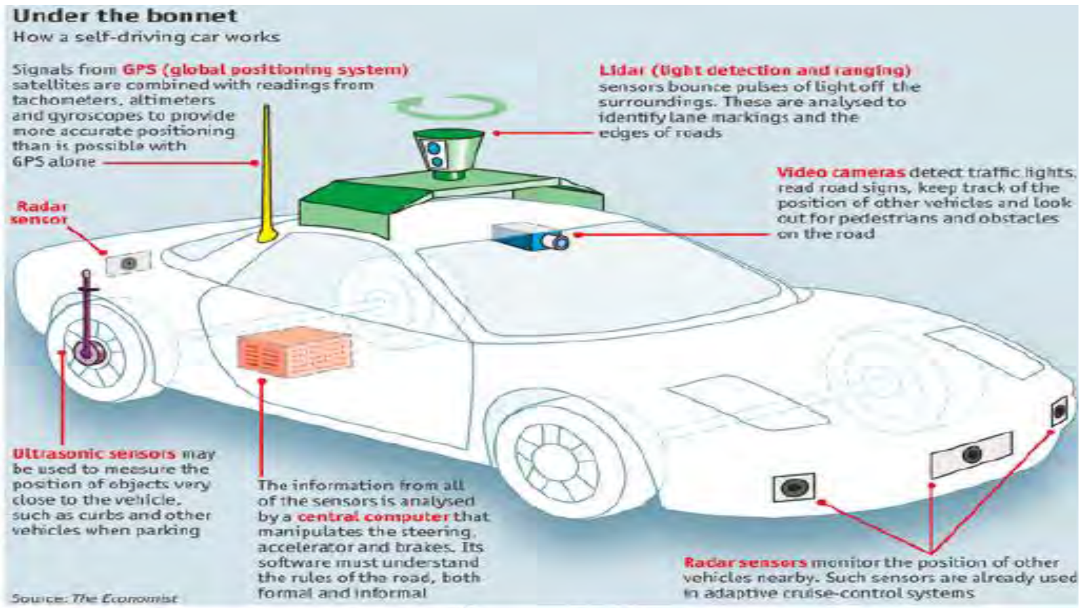


Fig: 2.1d Autonomous vehicle working model

This fig: 2.1d gives us the overview of all whole process that how it actually works and what sort of sensor, cameras used to make it autonomous [11].

CHAPTER 3
System Overview

3.1 Hardware:

For better visibility and mobility of the vehicle we have designed a custom car chassis with low cost mechanical parts including shock absorber, power steering, hanger etc. The entire mechanical system is divided into five subsystem. The subsystems are as follows:

3.1.1. Chassis: Chassis is the main skeleton of a vehicle. It contains all the other components on its body. If we go through a definition then it states that a car chassis is the Central foundation which clasp all the parts like wheel, Drive Engine, Body etc. In our case we have go through many designs to perceive the required design. Firstly we have tried the conventional car chassis design. In a conventional chassis system we have seen that there are two main pipe from where all the branches are emerge there self's. In this system we have discern that the stress distribution is not equal and the weight is too much. The conventional system is a heavy weight and heavy duty system that's why it can deal with the disparate stress dispensation. But in our case according to the requirements we have to manufacture a system with low amount of weight with maximum amount of rigidity. For this reason we have designed a new chassis. In our new system we have implemented the ladder and tube space frame design. In this design we have federate two system and named it as one single system. We have merged the ladder and tube with the space frame design. The ladder & tube design is usually used in the structural engineering for the high rises building to resist lateral loads. In this system inside a buildings beam one column is connected with another in a pattern that one's upper part is joint with the others rear part through another rigid part. For this motif it can save the high rises building from uneven load .In the space frame design there is a triangular which obviously has three node. Now the concept is if we apply force on the top most node then if the force is lesser than the rigidity of the part between the other two nodes then the stress can be equally distributed to the other two node which can reduce shape distortion [Fig:3.1.1a]. After combining these two different concepts we have named it as ladder and tube space frame design. In our cars chassis we also use two pipe as our main structure but we have input triangulation with the two main pipe which really increased the rigidity and easily distributed the stress in each strut. For making the chassis lighter than the conventional chassis we have used 1.5/1.5 inch square box pipe which is strong as well as less in weight. The total length of the chassis is 96 inch. In a conventional 4 seated car we have noticed that the average length of the chassis is 154 - 157 inch. But our system is consist of 2 seats that's why we have reduced the length of the chassis which helps us to decrease the total weight of the chassis.

Because of the heavy ladder & tube space frame design we have employed a number of triangulation inside our main chassis. Because of these triangular shape inside our chassis we have successfully diminish the chances of shape deformation due to unexpected shock from uneven roads. The space frame transmits the stress to each node of every triangle.

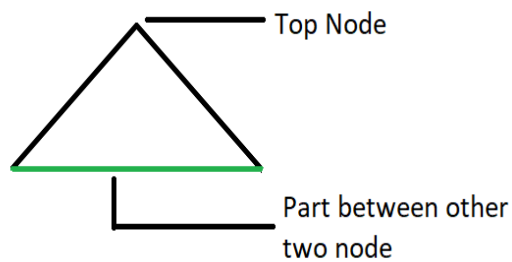


Fig: 3.1.1a Space frame

Fig: 3.1.1b Chassis CAD

3.1.2. Suspension: In this modern era of mobility we are enjoying better quality of ride than before. One of the most important part inside a vehicle which help us to relish on the road is suspension system. Now question is what is the suspension system? From the word itself Suspension we can understand that it is about to elevate a part from the surface to eventually suspend for diminishing the reaction of the forces of the surface on that specific part. In a car suspension system that specific part is usually the wheel. Now if we think that in developed countries like USA, Canada, England whom have the best quality of road, so why they need suspension on their vehicles? If anyone seat on the ground and making direct contact between their back and the surface then they can feel the vibration created by the other people who are passing by him through walking. Now think of a 1.5 - Ton metal which is running on the road at a speed of 60 km/h, how much vibration it can feel from other car or from the earth itself you can imagine. That's why suspension system is a must needed thing for a delightful ride while having the best quality of road. After a brief study of the existing suspension systems we can divided the suspension system into two different types. The first one is dependent suspension system [fig: 3.1.2a] and the other one is called the independent suspension system. So from the word dependent we can guess that there will be some kind of dependency of this type of suspension on something. In this type the axle of the car is rigid one single piece and one wheel is dependent on the other one. Because of the solid axle one wheel cannot move independently that's why the system is dependent. In this solid axle type of suspension we have notic ed two different kind of spring has been used. One is the leaf spring and another one is the coil spring.

The second type of suspension is the famous independent suspension. Again from the word independent we can understand that this system is not dependent on anything. In this type each and every wheel can move independently along with the axle. The joint with the chassis is made such a way that there is no dependency of one wheel movement on the other one. In the independent suspension system most popular and effective mechanism is the double wishbone arm mechanism. In this mechanism there will be two wishbone arm is dedicated for each wheel. The connection between the wishbone arms and the chassis has been built in such a

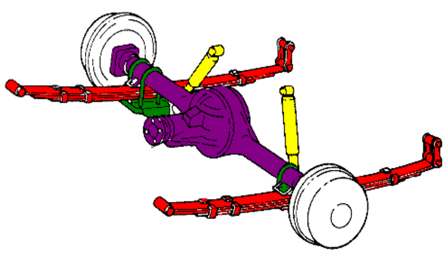


Fig: 3.1.2a Dependent Suspension System

way that the arms can move up and down and also can move forward and backward easily with the wheel without moving the chassis. For absorbing the shock there will be shock absorber placed between the two wishbone arms. Inside the shock absorber there will be a damper and a spring which can absorbed the shock while the wishbone will move [fig: 3.1.2b].

Fig: 3.1.2b Independent Suspension System

Now in our system we have used the modified version of actual double wishbone independent suspension system. The word modified is included because we have to modify the actual system according to our requirements. We have divided our suspension system into two part they are the front suspension and the rear suspension. On the front wheels which are actually free wheels, we have used pure double wishbone system. We have also include one shock absorber for each of the wheels. Firstly we have used the conventional dampers with the springs of a four seated car into our system, but we have faced some issues with that one. Those shock absorbers were too much heavy for our system because our first requirement was flimsy weight with maximum rigidity. Another problem was their height were very much large as those are from conventional four seated cars, which is not acceptable for our system because we have designed the chassis in a way that it can maintain the center of gravity almost at the middle because of the low height of the total system. So we have to design new shock absorber which are compatible for our system. While designing we have tried to reduce the height as well as the weight of the shock absorber. Now for the rear suspension we have modified the double wishbone suspension system. Generally we have seen that the engine of the cars are placed at the front part of the car, but in our system we have placed the engine at the rear portion because of the shape, that's why we cannot use the pure double wishbone system. We have used single wishbone with the axle. For absorbing the shock and support the lower wishbone we have placed the shock absorber between the lower wishbone and the chassis itself. For this modification we have the chance to reduce some weight as well as set the engine in a proper wand efficient way [fig: 3.1.2c].

Fig: 3.1.2c Front & Rear Suspension mechanism of our mechanism

3.1.3. Wheel: To achieve the mobility there is no other efficient way than wheels. After the invention of the wheels people can cover distance within a minimum time. One of the greatest invention in the history is the wheel. Now we are having the most advanced and modified wheels with so many features. In our car we have also used wheels as the main source of mobility. We have studied different size and shape and also experiment on our car for finding the designated one. First of all we have studied the conventional four seated cars wheels. In those cars we have noticed that the average diameter of the wheels are 22 inch. According to the total average length of a conventional car this size is perfect. From our collected data we can say that the standard length of a regular car is between 154 – 157 inch and the standard width of a car is from 62 to 65 inch. So after a brief study of terra-mechanics we have understand that the diameter 22 inch is most effective for a standard size car. In our system the total length of the car is 96 inch and the width is 40 inch. The distance between front wheel center and rear wheel center is 65 inch. After all the calculation we have selected two different size and shaped wheels for experiment. Firstly we have selected a wheel with a diameter of 24 inch. The reason behind selecting the wheel is our country's road. In our country maximum roads have trench on its surface. So overcoming those surfaces smoothly and for maximizing the distance cover we have selected those wheels. After several test drive with those wheels we have noticed some problem. For the large size of wheels there is extra weight on the car and the center of gravity is also moved from the middle for extra height. The rotation per minute is also reduced on the wheel. After all those problems we have select another wheel with a diameter of 16 inch. The width of the wheel is 6 inch. The reason behind selecting this wheels is to reduce the weight and to gain the perfect center of gravity. After several test drive with this wheel we have noticed that the rotation per minute is increased and it also can overcome those uneven roads easily. After comparing the two sizes which are 24 inch and 16 inch diameter we have seen that the one with the 16 inch diameter is perfect for our system. We have also faced some other problem with the wheel. While having test drive we have noticed that sometime the car is not moving straight. Another problem we have found after test drive is one tire from the left side has the most erosion than other three tires. After studying with the two problems we have found that our front left wheel is not perfectly align and this tire is not properly balanced with the other three. After align the wheel perfectly we have noticed that the car is moving perfectly straight. For stopping the early erosion of a specific tire we have balanced all four tire with each other. After the wheel alignment and tire balancing those problems were solved.

Fig: 3.1.3 24 inch and 16 inch wheel

3.1.4. Steering: In a vehicle it is very much important to give direction to the vehicle by the diver. For giving a proper direction there is a mechanism called steering generally used in every vehicle except the Train. In a steering system there are many components connected with each other which helps the vehicle to follow the required path smoothly. If the steering system of a vehicle is not working properly then the vehicle may not follow the desired path. Inside a conventional four seated car steering system there are a solid axle rotate linearly through a system and the two tip of the axle are connected with the steering knuckle which contains a wheel. So basically when the axle move linearly then it rotate the wheels trough the steering knuckle and make the steering work. After our brief study we have found out that there are various kind of steering mechanism exist in the vehicle world. We have shortlisted some most efficient system for our driver less car. The first system is called rack & pinion steering system which is mostly used in the vehicle industry. From the name we can understand that it is something works using the pinion and rack. In a steering system there are certain components which are interconnected with each other, means those parts are dependent on each other. The first part of a steering system is the steering wheel which is connected with a steering shaft. So in the rack and pinion system a pinion is connected with the steering shaft, the pinion is placed on a rack which is actually a solid axle with gear on itself. When the driver rotates the steering wheel then the pinion is also rotate and also it move the rack linearly. The rack is connected with the front two wheels and make the steering functional. The second system is called recirculating ball steering mechanism. In this system we have seen that one recirculating ball gear box is connected with the steering shaft. In the recirculating gearbox there are a steering shaft which has worm gear on it and a ball nut frame. This gear box is connected with a sector gear which has a pitman arm on it. Now when the steering shaft is rotate by the driver then the circular motion is passed to the recirculating ball gear box through the worm gear shaft, then the gear box rotate the sector gear which passes the motion to the pitman arm. After receiving the motion pitman arm rotate the track rod which is connected with the pitman arm. Then the track rod move the tie rod linearly which is directly connected with the front wheels. This is how the recirculating ball steering works [fig: 3.1.4]. The third system is power steering mechanism. There are two different kind of power steering mechanism, they are the hydraulic power steering system and the electric power steering system. The hydraulic power steering system is mainly based on hydraulic pump and fluids. In this system there is a pump placed inside the steering system to control the flow of fluid motion. There is a piston connected with the wheels which is control through the fluids. So when the driver rotate the steering shaft then the fluid direction control valve rotate and the pump release the fluid, this fluid then go to the piston and move the piston linearly which rotate the wheels. This system is very much helpful for the drivers because in the conventional steering system driver manually rotate the gear to move the front wheels which need much force, but in this system driver just move the valve and rest of the work is done by the help of fluid and pistons. Another type of the power steering mechanism is the electric power steering system. So in this system there is an electric motor mounted on the steering gear box. There are multiple sensors are placed inside the gearbox along with the motor. So when driver give any input on the steering wheel then the sensors can trace it and power up the motor, after that the motor generate sufficient amount of torque to rotate the gear box as drivers input and helps the driver to rate the steering. In this system the driver needs to apply less amount of force to rotate the steering because of the motor. If we compare both of the power steering mechanism then we can see that in a hydraulic power steering system a pump is always turn on and consume power from the engine fuel but in the electric power

Fig: 3.1.4 Electric power steering in our system

Fig: 3.1.5 Electric drive engine of our system

steering system the motor is turned on when it trace any input from the driver to the steering wheel. So comparing two methods we can say that the electric power steering mechanism is more efficient. Now after a brief study of all these mechanism we have selected the electric power steering mechanism for our system. There are couple of reason behind this decision, first of all this mechanism saves power, secondly as our system is autonomous so we have to drive the steering by itself so using the motor we can easily programmed it as it is a DC motor, lastly from the data we know that the performance of the electric power steering motor is remarkable from any other system. So after selecting the mechanism we have search for the electric power steering gear box along with the motor and axle. We have found the regular size system which is very much large for our system. So solving this problem we have did some reverse engineering and modify the system as our requirement.

3.1.5. Drive Engine: Now a days a word is more popular in the world environment arena which is "Green". Everyone who are concern about the nature gives advice to make everything green. Now what is the meaning of this movement? It means that whatever we are doing for our living we have to do it in a way which is environment friendly. For example we can take the transportation system. If we see outside we can find that maximum number of vehicles are using fuel or gas which harms the environment. If we convert the vehicle drive system in such a way that is not harmful for the nature then it will name as a green transportation system. As a consequence the electric engine powered engine is introduced. In this system the vehicles will run by the electric power which do not emits any harmful gas in the environment and helps us to make an ecofriendly and green transportation system. Considering all those facts we have selected the electric powered engine for our driver less car. We have selected two system for experiment on our car. In the first system we have a Brushless DC motor, we have built the customized axle for the system. In our axle we have placed chain sprocket at the middle and drums at the two tip. So the chain sprocket is connected through a chain with the Brushless DC motor which will run the axle. The drums are placed to attach the rear wheels. After finishing the setup we have done several test drive with this setup. We have found some problems with this system, like when the car drive through any uneven road or drive little fast then the chain fall from the desired place, for this set up the rear suspension with the single wishbone doesn't work efficiently. After having problems with this system we have decided to try another system. In the new system there is also a brushless DC motor but the motor is mounted with the drive axle in a way that there is no need of chain driven motion. There is a differential gear box attached with the motor which helps us to drive both of the rear wheel at a time. The system has also pre-installed drums in it for mounting the wheels. After installing the new system in our car we have done couple of test runs. As there are no chain driven system inside the new mechanism so falling of chain is not creating an issue this time. Even when we drive the car fast this time then there is no chain falling happened because of the customized differential gear box. So after studying both of the system we have found that the second mechanism is more efficient than the first one, so we have selected the second one for our car. The drive voltage for our electric engine is 48V with a power of 1000W. The rotation per minute of the shaft is between 3000 – 3300 with a speed of 25 – 35 km/h. The speed ratio of the electric engine for the passenger is 1:10. The total efficiency of the engine is 85%. For having DC motor on the system we can easily integrate the engine with our electronics part and can programed it. Considering all the aspects this electric engine is turn out the best choice for our system [fig: 3.1.5].

3.1.6 Sensor: A sensor is a device which can observes it surroundings and records data, gives us feedback even responses to it. So we can say sensor is playing one of the most vital roles in an autonomous car's mobility and navigation. By receiving data via sensors an autonomous car's ECU analyzes the road condition and take a decision what it will do. Now question may arise that which sensors is being used in an autonomous car? Obstacle Sensor, Camera, RADAR (Radio Detection and Ranging) and LIDAR (Light Detection and Ranging) are counted as the three main groups of sensor systems. Some company uses long range Ultrasonic sensors for parking but they are not important for driving. Due to the use of CMOS image sensors the camera can easily detects any object clearly from a long distance. Along with the cameras, radar systems give us precise information about the speed and distance of an object. Also, LIDAR sensor provides 360 view around the car.

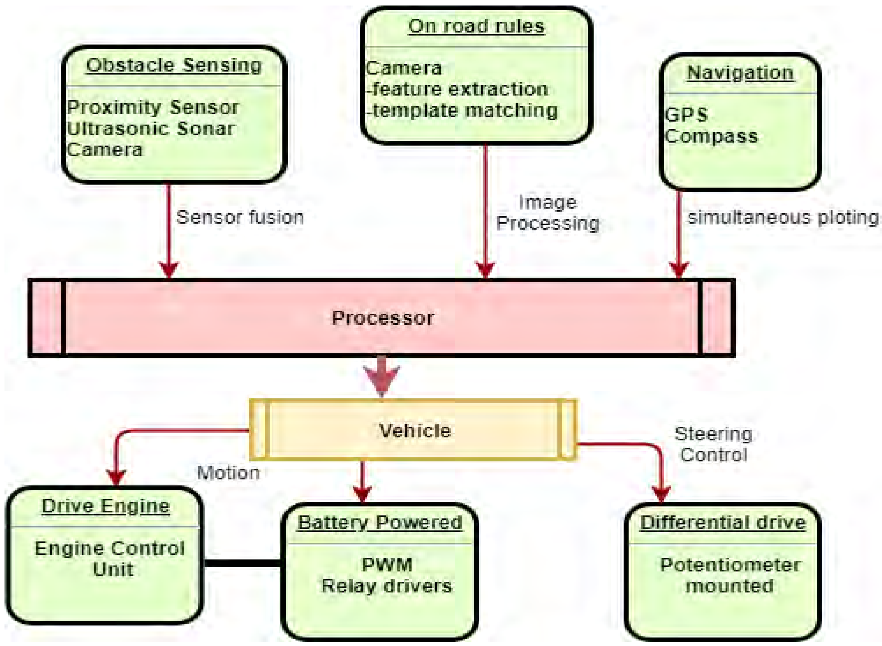


Fig: 3.1.6 Onboard System

In our vehicle the camera module we have integrated is the Raspberry Pi Camera Module v2 which has a Sony IMX219 8-megapixel sensor. The vision system we developed is in mid-range. For the obstacle avoidance we have used 6 long range ultrasonic sonar sensor HC-SR04 (2 in front, 2 at back and 2 at both side). For location and magnetic orientation U-blox 6 based NEO-6 series GPS module and an HMC5883L three-axis magnetic module is being used. Also, there will be an android device attached to the vehicle which will provide accurate GPS and magnetic orientation data. For the motion and posture of the vehicle MPU-9250 sensor is used which is a 9-axis Motion-Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer and a Digital motion processor.

3.1.7 Electronics: We designed the entire electrical system using Proteus 8.0 and manufactured them on printed circuit board (PCB) which provides a convenient plug and play connection system. The entire electronics system consists of STM32f446re an high-performance ARM®Cortex®-M4 32-bit based microcontroller, ATmega328P based Arduino Uno, MCP – 2515 can module, one four channel relay module, one two channel relay module and some wires and connectors. HL-52S 2/4 channel relay module is 2/4 relays with rating of 10A @ 250 and 125 V AC and 10A @ 30 and 28 V DC.

a. ECU (Electronic Control Unit): The electronic control unit is the main brain of the entire system which includes STM32f446re. It is connected with every single unit of the vehicle. The ECU is connected via the CAN bus, which acts as a central networking system.

b. CAN bus: Controller Area Network (CAN) is a serial communications protocol which is built to allow microcontrollers and peripherals to communicate with each other and it doesn't need any host computer to do it. It provides higher efficiency during real time control and maintains a high level security. The CAN bus system was first developed by Robert Bosch and officially released in 1986 and came on the market in 1987 which was produced by Intel and Philips [12]. We developed can nodes using MCP – 2515 can module which we can easily control any can bus device by Serial Peripheral Interface (SPI) with MCU such as Arduino. To design our own can bus system, we have implemented three CAN to control steering with précised rotational degree, engine control with speed and instant braking. Also other CAN includes sensor data and light control.

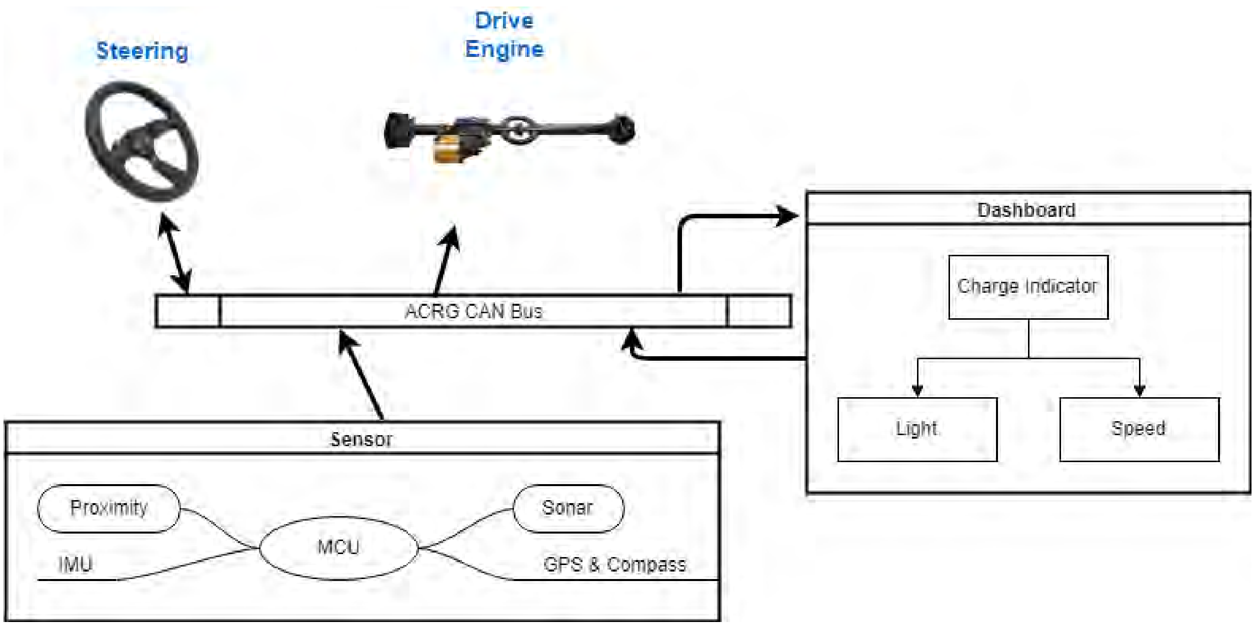


Fig: 3.1.7b CAN System Schematic

3.2 Software: The software system establishes a very user friendly environment to control the vehicle manually as well autonomously. The systems' main aspect is to provide a reliable and easy to use control interface of the vehicle and to retrieve accurate up to date information of the surroundings.

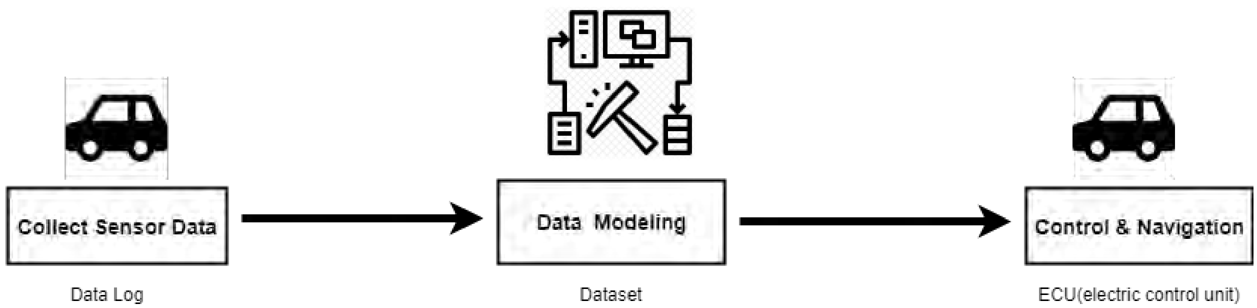


Fig: 3.2 Data Flow

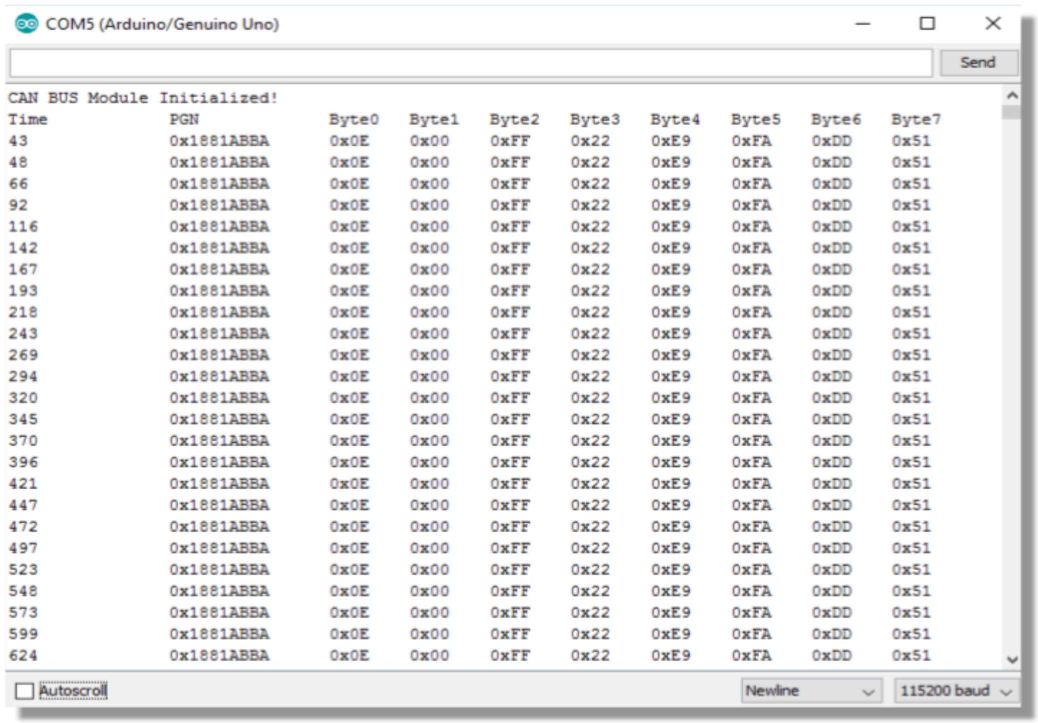
3.2.1 Sensor Data Calibration: The ultrasonic sensors emits an ultrasound at 40 000 Hz which travels through the air and if there is an object or obstacle on its path bounce back to the module. Considering the travel time and the speed of the sound we calculate the distance.

Duration=travel time of the sound wave,

Distance= (Duration*v)/2;

We know, Speed of sound, v = 340 m/s

Equation of motion, s = v*t [where s-> distance, v->velocity, t= time]



COM5 (Arduino/Genuino Uno)

Send

CAN BUS Module Initialized!

Time	PGN	Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
43	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
48	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
66	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
92	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
116	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
142	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
167	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
193	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
218	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
243	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
269	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
294	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
320	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
345	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
370	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
396	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
421	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
447	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
472	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
497	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
523	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
548	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
573	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
599	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51
624	0x1881ABBA	0x0E	0x00	0xFF	0x22	0xE9	0xFA	0xDD	0x51

Autoscroll

Newline

115200 baud

Using the mcp_can.h library and MCP2515_CAN module we create a program

which transmit CAN message and receive the can message repetitively. The length of the identifier is either 11 bits in length. The data is anywhere from 0 to 8 bytes in length.

CAN Data transfer process consist of supplying, sending, receiving, checking and accepting data.

SF	Message Identifier	Control	Data	CRC	ACK	EF
1 Bit	11bits for 2.0A 29 bits for 2.0 B	6 bits	up to 64 bits	16 bits	2 bits	7 bits

Fig: 3.2.1b CAN Data Array

3.2.2 Camera Vision: Camera vision is a must for spotting things like lane lines on the highway, speed signs, and traffic lights. With better machine vision, the vehicle will be able to identify everything it see and navigate accordingly. We are using Python 3.6 programming language for its simplicity in computer vision eco-system. Also we are going to use OpenCV 3.4.1 to process the input images to detect lane lines held within as well as for finding out any discontinuity or cross section of the lane. Additionally, numpy-1.14.5 and matplotlib-2.2.2 are used to do transformations and rendering of image data. For the vehicle detection and tracking we use TensorFlow Object Detection API, which is an open source framework built on top of TensorFlow to construct, train and deploy object detection models. We use a lightweight model: ssd_mobilenet_v1_coco that is based on Single Shot Multibox Detection (SSD) framework with minimal modification. The COCO dataset contains images of 90 classes, with the first 14 classes all related to transportation, including bicycle, car, and bus etc. [13]

```
category_index={1: {'id': 1, 'name': u'person'},
                2: {'id': 2, 'name': u'bicycle'},
                3: {'id': 3, 'name': u'car'},
                4: {'id': 4, 'name': u'motorcycle'},
                5: {'id': 5, 'name': u'airplane'},
                6: {'id': 6, 'name': u'bus'},
                7: {'id': 7, 'name': u'train'},
                8: {'id': 8, 'name': u'truck'},
                9: {'id': 9, 'name': u'boat'},
                10: {'id': 10, 'name': u'traffic light'},
                11: {'id': 11, 'name': u'fire hydrant'},
                13: {'id': 13, 'name': u'stop sign'},
                14: {'id': 14, 'name': u'parking meter'}}
```

3.3.3 Mapping and Localization: Using a GPS module we calculate the latitude and longitude with a 5 meter error margin which is experimented in open environment with preloaded map. The Compass sensor is used along with the GPS module to find out the exact vehicle direction. The software combines both GPS and magnetometer values in coordination with the visual data from the camera to achieve simultaneous localization and mapping. For a target position we calculate the distance and initial bearing between the two coordinates using the 'haversine' formula [14].

Haversine formula:

$$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$$

$$c = 2 \cdot \operatorname{atan2}(\sqrt{a}, \sqrt{(1-a)})$$

$$d = R \cdot c$$

where φ is latitude, λ is longitude, R is earth's radius (mean radius = 6,371km); note that angles need to be in radians to pass to trig functions!

The current heading will vary as you follow a great circle path (orthodrome); the final heading will differ from the initial heading by varying degrees according to distance and latitude [15].

Formula: $\theta = \operatorname{atan2}(\sin\Delta\lambda \cdot \cos\varphi_2 , \cos\varphi_1 \cdot \sin\varphi_2 - \sin\varphi_1 \cdot \cos\varphi_2 \cdot \cos\Delta\lambda)$

where φ_1,λ_1 is the start point, φ_2,λ_2 the end point ($\Delta\lambda$ is the difference in longitude)

This is the half-way point along a great circle path between the two points.

Formula:

$$B_x = \cos\varphi_2 \cdot \cos\Delta\lambda$$

$$B_y = \cos\varphi_2 \cdot \sin\Delta\lambda$$

$$\varphi_m = \operatorname{atan2}(\sin\varphi_1 + \sin\varphi_2, \sqrt{(\cos\varphi_1 + B_x)^2 + B_y^2})$$

$$\lambda_m = \lambda_1 + \operatorname{atan2}(B_y, \cos(\varphi_1)+B_x)$$

Once we calculate the distance, initial bearing and midpoint we start the navigation of the vehicle using mapbox sdk with android.

```python
def calculateDistance(self, clat, clon, calt):
  dlat = math.radians(tlat-clat)
  dlon = math.radians(tlon-clon)

  #distance
  d = math.sin(dlat / 2) * math.sin(dlat / 2)+math.cos(math.radians(clat)) * math.cos(math.radians(tlat))* math.sin(dlon / 2) * math.sin(dlon / 2)

  c = 2 * math.atan2(math.sqrt(d), math.sqrt(1 - d))
  distance = R * c * 1000 # convert to meters
  height = talt-calt
  distance = math.pow(distance, 2) + math.pow(height, 2)
  distance = math.sqrt(distance)

  print('Distance: ' + str("%.2f" % distance) + 'meters')
  return distance

def calculateHeading(self, clat, clon, calt, head):
  dlat = math.radians(tlat-clat)
  dlon = math.radians(tlon-clon)

  #angle calculation

  y = math.sin(dlon)*math.cos(math.radians(tlat))
  x = math.cos(math.radians(clat))*math.sin(math.radians(tlat))-math.sin(math.radians(clat))*math.cos(math.radians(tlat))*math.cos(dlon)

  temp = math.degrees(math.atan2(y, x))
  angle = (temp + 360) % 360

  print('Angle: ' + str("%.2f" % angle) + 'degree')

  heading = head-angle
  print(heading)
  return heading
```

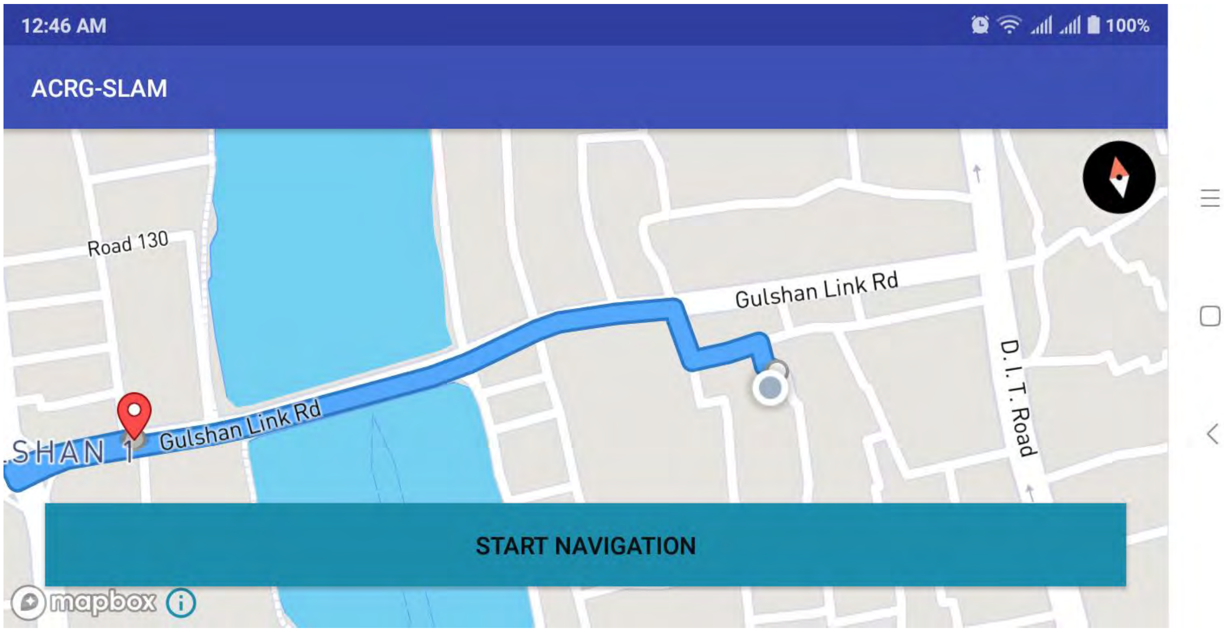


Fig 3.3.3 Mapping and navigation

CHAPTER 4

Methodology

After collecting all the sensor data the main job is to endlessly improve the control and navigation system of the vehicle. We have divided the method into two approach- one is learning based control, another one is dynamic control. In the learning based approach first of all we have implemented image processing to detect lane of the road, object recognition system including recognition of variety of vehicles using TensorFlow object API.

4.1 Dynamic Control:

There are many situations when the driver needs to move their vehicle a short distance at a time. That can mean climbing in and out of the car over and over again. A dynamic control with external steering feature, the car can be controlled from the outside. The system gives the control of engine, steering, brakes and lights through a remote control or wired steering device provided by an external supplier. We have developed a dynamic steering system to control the car through remote. Moreover, for controlling the car we have developed an android application. The user interface of the application is quite simple so that anybody can easily operate this application. A Bluetooth module installed in the chassis of the car is used to communicate between the android devices via application. Now question may arise that how it works? For example, we want to make a left turn of our car. A signal is sent to the dynamic steering of our car, which executes the command and the car turns left. The feature is well suited for parking the car in a narrow space, uneven road condition.

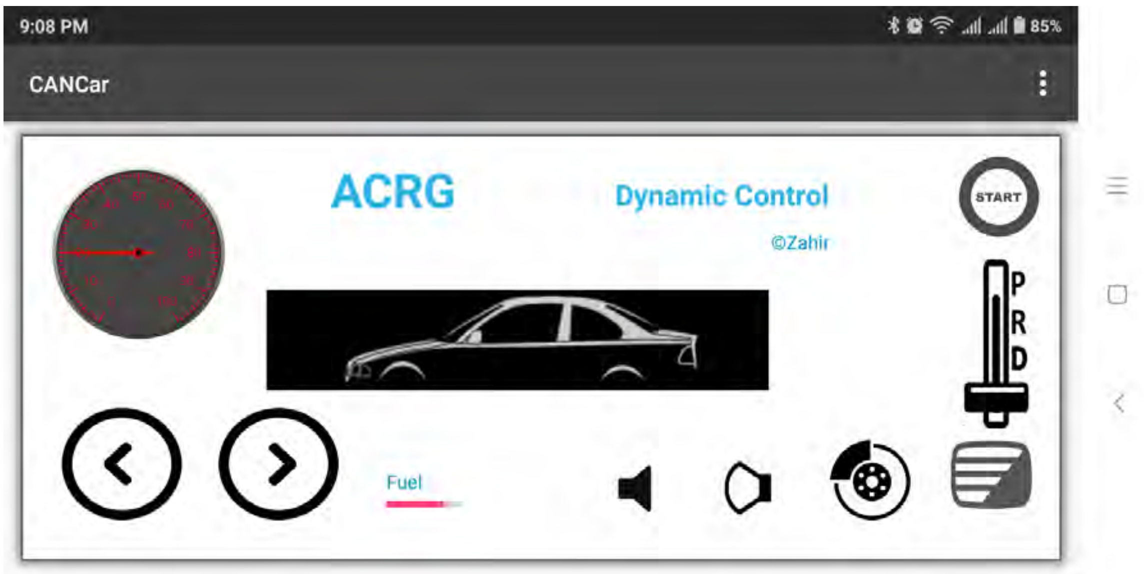


Fig: 4.1. UI of ACRG application

Thinking about the majority of the people the application is designed. It provides a very user friendly environment to control the vehicle. It is developed using android 6.0 API level 23 so that everyone can get the application easily.

4.2 Learning Based Control:

To achieve level 2 automation we have used and developed several algorithm using image processing and machine learning.

4.2.1 Lane Detection:

One of the most important parts of the self-driving car algorithm is Lane detection. Cameras installed in the body of the car is used to capture real time 2D images of the road and its surrounding.[16] If the vehicle safety distance is too small, the system will notify the driver to avoid dangerous situations. From the image that captured by the cameras on board controller should know the limits of the lane and based on that it will warn driver when the vehicle is too close to the lanes. Keeping the self-driving car in the middle of the road is an obvious task to avoid all the accidents.

There are four major steps in a typical lane detection algorithm.

- Select the Region of Interest (ROI)
- Image Preprocessing
- Edge Detection
- Hough Transform to decide the lane markings

a. Select the Region of Interest:

Color images are taken by the cameras. We all know that each pixels of a picture is made up with the combination of R, G and B color components and it contains huge information. As it takes a long time to process the whole image, the algorithm select the region of interest from the original image so that it will only process those pixels which is required to detect the lane lines. Due to this process the algorithm gained a better time complexity and a better speed than previous.

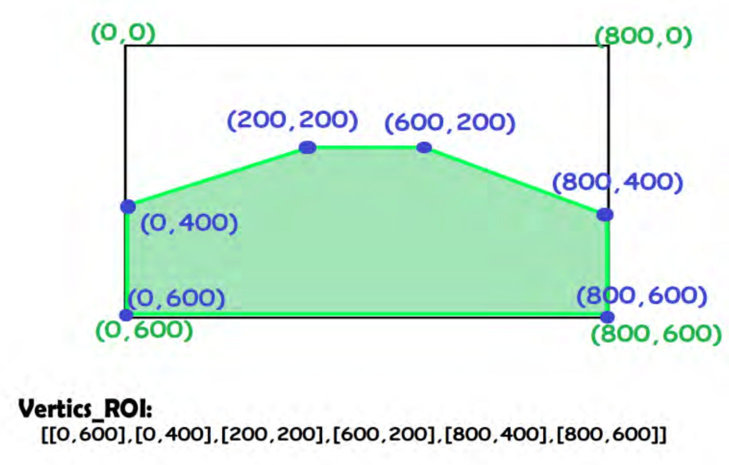


Fig: 4.2.1a. Region of Interest

b. Image Preprocessing: Image preprocessing is a step to remove noise from the images before it starts processing stage. Grayscale conversion of color image, median filter to remove noise and gray stretch are the processes of the image preprocessing. Because of the grey stretch process we can easily determine the difference between the lane and the road.

$$L(x, y) = 0.21\ R(x, y) + 0.72G(x, y) + 0.07\ B(x, y) \ldots\ldots (1)$$

```python
def process_img(image):
    original_image = image
    # convert to gray
    processed_img = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
    # edge detection
    processed_img =  cv2.Canny(processed_img, threshold1 = 200, threshold2=300)

    vertices = np.array([[100,500],[100,300],[200,200],[400,200],[600,300],[600,400],], np.int32)
    vertices_2 = np.array([[100,500],[100,400],[400,400],[600,400],[800,400],[800,600],], np.int32)
    processed_img = roi(processed_img, [vertices])
    original_image2 = roi(original_image, [vertices_2])

    lines = cv2.HoughLinesP(processed_img, 1, np.pi/180, 180,      20,       15)
    try:
        l1, l2 = draw_lanes(original_image,lines)
        cv2.line(original_image, (l1[0], l1[1]), (l1[2], l1[3]), [0,255,0], 30)
        cv2.line(original_image, (l2[0], l2[1]), (l2[2], l2[3]), [0,255,0], 30)
    except Exception as e:
        print(str(e))
        pass
    try:
        for coords in lines:
            coords = coords[0]
            try:
                cv2.line(processed_img, (coords[0], coords[1]), (coords[2], coords[3]), [255,0,0], 3)


            except Exception as e:
                print(str(e))
    except Exception as e:
        pass

    return processed_img,original_image2
```

Where R, G, B stands for Red, Green, Blue components of an image and x, y defines the position of a pixel.

By using Equation (1) we can convert an RGB image to Gray scale format.

Under the method of image filtering there are two sub methods are available, one is the frequency domain filtering and the other one is spatial domain filtering [17]. Frequency domain filtering is more complex and slower than the spatial domain filtering. After removing the noise from the original image, spatial domain filtering preserve the edge details of the image.

c. Edge detection: We perform edge detection on the result of the preprocessing. The main purpose of this edge detection is to detect lines around the objects. Canny edge detection is a popular edge detection method which was introduced by John F Canny, University of California, Berkeley in 1986. Gaussian filters, intensity gradient changes are used to determine the edges [18]. [Fig: 4.2.1c]

Fig: 4.2.1c. Canny Edge detection output

d. Hough Transform:

$r = x \cos\theta + y \sin\theta$ ……. (2)

Equation (2) is used to detect straight lines and other normal shapes by a simple mathematical model of a straight line in a two axis system. This is called Hough transformation. We get some points from the edge detection algorithm and these are part of the lane markings. We used Hough transform to create a line through these points. In a two dimensional co-ordinates format of r and θ, it creates

Fig: 4.2.1. Hough Line

multiple lines by connecting points. A specific r and θ intersects in a particular point and this is common to all other lines. Another characteristics of this line is it will pass through all the points of region of interest.

4.2.2 Vehicle Detection and Tracking: For this purpose we use TensorFlow Object Detection API, an open source framework. Also it comes with a collection of detection models pre-trained on the COCO dataset that are well suited for fast prototyping. To track other vehicle Kalman filter is used which has the following features-

- Prediction of object's future location
- Correction of the prediction based on new measurements
- Reduction of noise introduced by inaccurate detections
- Facilitating the process of association of multiple objects to their tracks

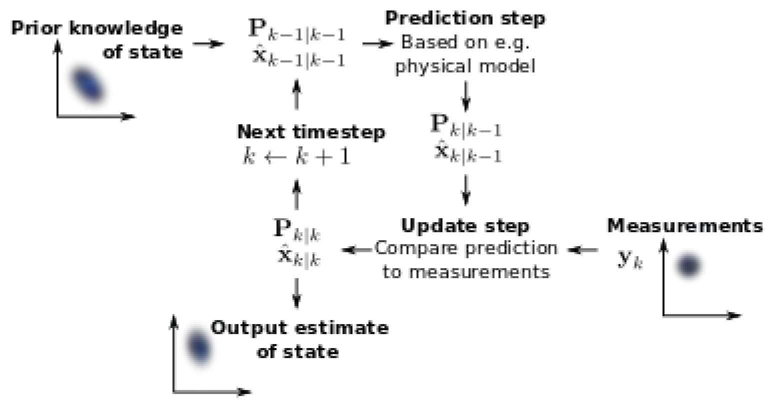


Fig: 4.2.2a Kalman filter

The Implementation of the Kalman Filter:

```
def update_R(self):
    R_diag_array = self.R_ratio * np.array([self.L, self.L, self.L, self.:
    self.R = np.diag(R_diag_array)

def kalman_filter(self, z):
    x = self.x_state
    # Predict
    x = dot(self.F, x)
    self.P = dot(self.F, self.P).dot(self.F.T) + self.Q

    #Update
    S = dot(self.H, self.P).dot(self.H.T) + self.R
    K = dot(self.P, self.H.T).dot(inv(S))
    y = z - dot(self.H, x)
    x += dot(K, y)
    self.P = self.P - dot(K, self.H).dot(self.P)
    self.x_state = x.astype(int)

def predict_only(self):
    |
    x = self.x_state
    # Predict
    x = dot(self.F, x)
    self.P = dot(self.F, self.P).dot(self.F.T) + self.Q
    self.x_state = x.astype(int)
```

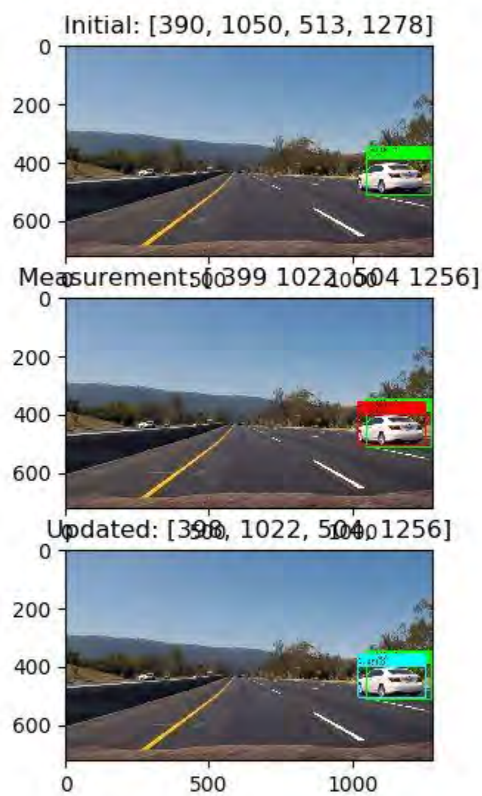


Fig: 4.2.2b Vehicle Detection

CHAPTER 5

Experimental Analysis

Several experiments were conducted following the completion to ensure proper functionality of the vehicle. The experiments can be split into two steps:

5.1 System Test:

With CAN, we send and respond to messages over the CAN bus. A message contains an identifier and data. The length of the identifier of the identifier is either 11 or 29 bits in length. We couldn’t manage to send data over 8 bits and identifier of 29 bits.

5.2 Game Play Simulation:

We use Udacity’s self-driving car simulator as a test-bed for training an autonomous car. We read frames directly from the desktop rather than working with the games’ code itself. Then we made the program to learn whatever we put in front of it based on frames as input and key presses as output. For training we need both features and labels. The feature sets are the pixel data from the screen we grab and the labels are the key inputs. Now to make a successful test run we need an area where the road has lane system and strictly followed traffic signals. So, we are planning to make some test run in the Dhaka cantonment area or Bashundhora 300 feet area. We are trying to take permission from the higher authority to check our autonomous feature in the road. But, we have already controlled our car via mobile application in our university premises and hopefully we can get permission from the authority regarding the test run of our self -driving car.

When one car is passing another car, the two cars can be very close to each other. This can fool the detector to output a single (and bigger bounding) box, instead of two separate bounding boxes.

Due to lack of high configuration portable computer we couldn’t use high performance model of tensorflow and algorithm. However, we are able to simulate a game by using our algorithm and also we are able to control our car by our mobile application.

CHAPTER 6

Conclusion

In this advanced phase of world, technology is the blessing from science that we can rely on. If we see in the market almost every giant companies are running after one thing that is autonomy. Everyone trying to include some sort of autonomy in their project. Now question arises why is everyone running after this thing? If we notice our daily life then we can see that human beings are now search comfort in every sector of their life. For example we all do one thing after wake up from sleep that is brushes our teeth. Now company's like Oral-B offering electric toothbrush, so people need to just put it inside the mouth and then rest of the work will be done by itself. So we can understand from this example that people are looking for less amount of work with great comfort. Now the automobile industry also interested to fulfill customers crave for comfort by implementing autonomous drive system on their vehicles. It now becomes the new trend of this industry. Everyone is now trying to achieve the next generation of mobility by this feature. In our research we have also tried to successfully implement the autonomous features. In our system we have implemented dynamic control, low cost car can bus system, lane detection through image processing, mapping successfully. Our driverless car opens new platform in developing country like Bangladesh to research about this topic and developed the automobile industry. If we get more support both technically &

financially then we can upgrade our system in near future. We are planning to integrate sensors like radar and Lider into our system for better navigation and distance measurement. Moreover for more efficient data collection we can add actual car can bus system. A very efficient and fast charging system can be installed into the system for quick charging in future. In our country if government and investors assist in this kind of research work then this sector can be great opportunity for our country. Autonomy in the vehicle industry is a new technological trend and if we want to stay on the race then we have follow the trend and work accordingly.

Fig: 6. Self-driving car developed by ACRG

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