Automated Driving

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Team Violet

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Prepared for

CS83 Software Project Management

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Revision History

Date	Version	Author	Comments
09/18/2020	Alpha	Team Violet	Initial Project Requirements
09/28/2020	Beta	Team Violet	Added nodes to project requirements
10/05/2020	Gamma	Team Violet	Added nodes to project requirements
10/12/2020	Delta	Team Violet	Initial Project Plan
10/19/2020	Epsilon	Team Violet	Added Resource & Time Estimation
10/26/2020	Zeta	Team Violet	Added Work Breakdown Structure
11/02/2020	Eta	Team Violet	Added Project Network Diagram
11/09/2020	Theta	Team Violet	Added Risk Enumeration
11/16/2020	Iota	Team Violet	Performed Risk Quantification

Documentation Approval

The current Software Requirement Documentation has been approved by**:**

Name	Title	Date
Dr. Samir Padalkar	Instructor-CS683	

Project Report Documentation

The SRS of Automated Driving will consist of the following features. Project Overview statement, Problem, Objectives and Risks.

Project Overview Statement	Project Name Automated Driving	Project Team Team Violet

Problem

The United States alone itself witnesses around 32,000 deaths each year in the crashes. And around 2 million people are injured and of these most of the crashes are the result of human error. Automation in the vehicle industry can reduce down the human error which in turn would reduce the fatalities and mishaps.

Goal

The underlying goal is to create a self driving system that is less prone to accidents than humans. The system would be developed by deep study and understating of the real- world problem. The system will be time learning and data from all the vehicles would be used together to refine the automation to trim off the percentage of errors. This report would be the way to deliver the solution for automated vehicle systems by amalgamation of various technological advancements.

Objectives

Model the behavior of the automated vehicle “driver”/pilot and forecast development of acceptance for different scenarios of introducing automation.

Gathering aggregated data on user acceptance, behavior, accident/incident types and other estimated risks, training needs, HMI evaluation, focusing especially on Pilots’ evaluation.

Exploring the extendibility, optimization, and sustainability of the simulation platform suite.

Success Criteria:

-When the cars can successfully avoid sudden objects within a fraction of a second.

-When a substantial reduction in accidents is attributed to self driving vehicles.

Risks:

Risks before product release are outlined in risk enumeration. Incalculable risks after production are listed before:

- The system’s security may not be enough, causing more accidents due to the increased risk of being hacked and forced into crashing (Hacking is possible)
- The system running into a bug not resolved in testing and causing a lapse of judgement in the car’s ability to self drive.
- Human override causing the car to crash
- Adverse weather conditions could obscure sensors

Prepared By	Approved by	Date
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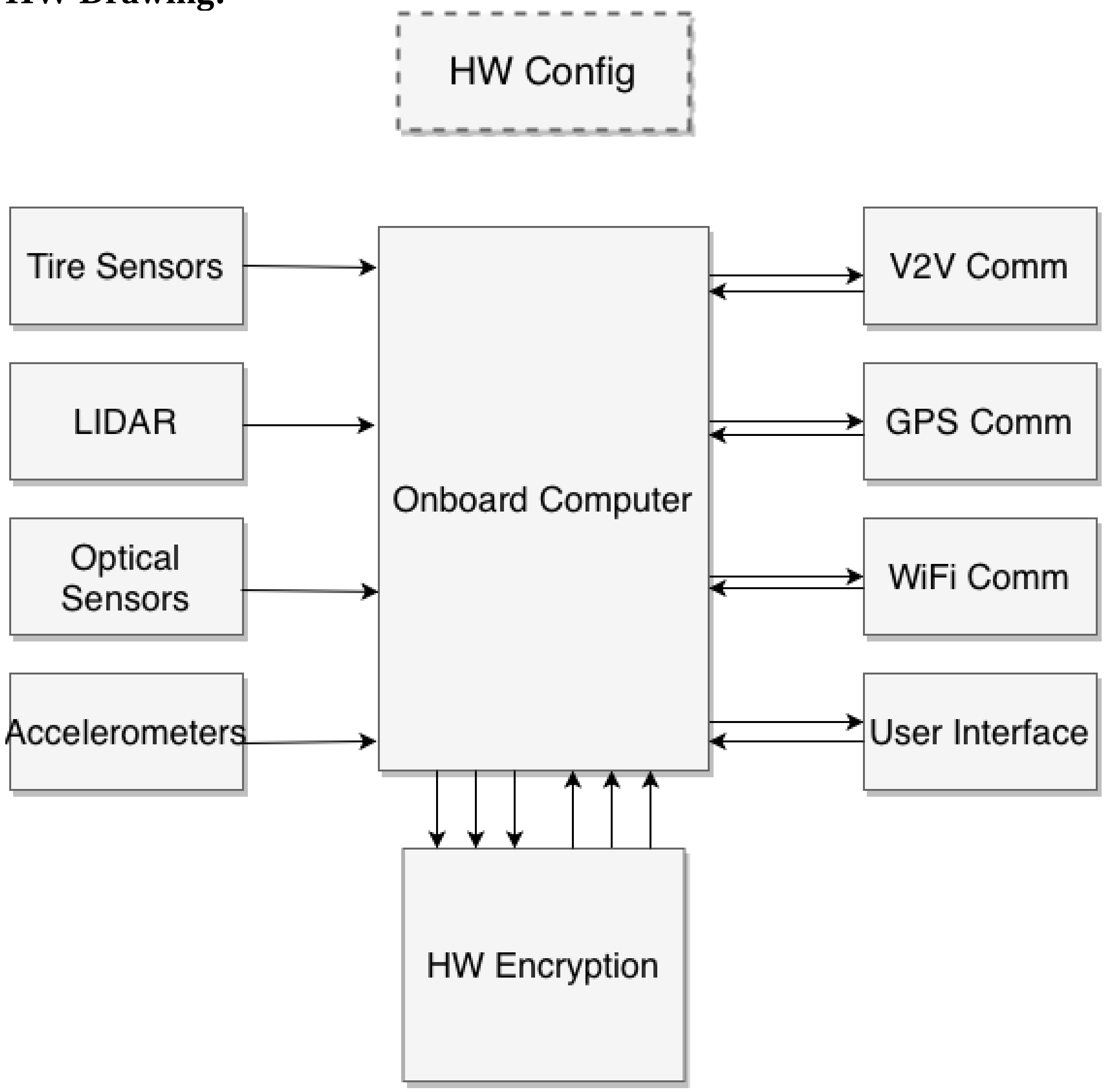
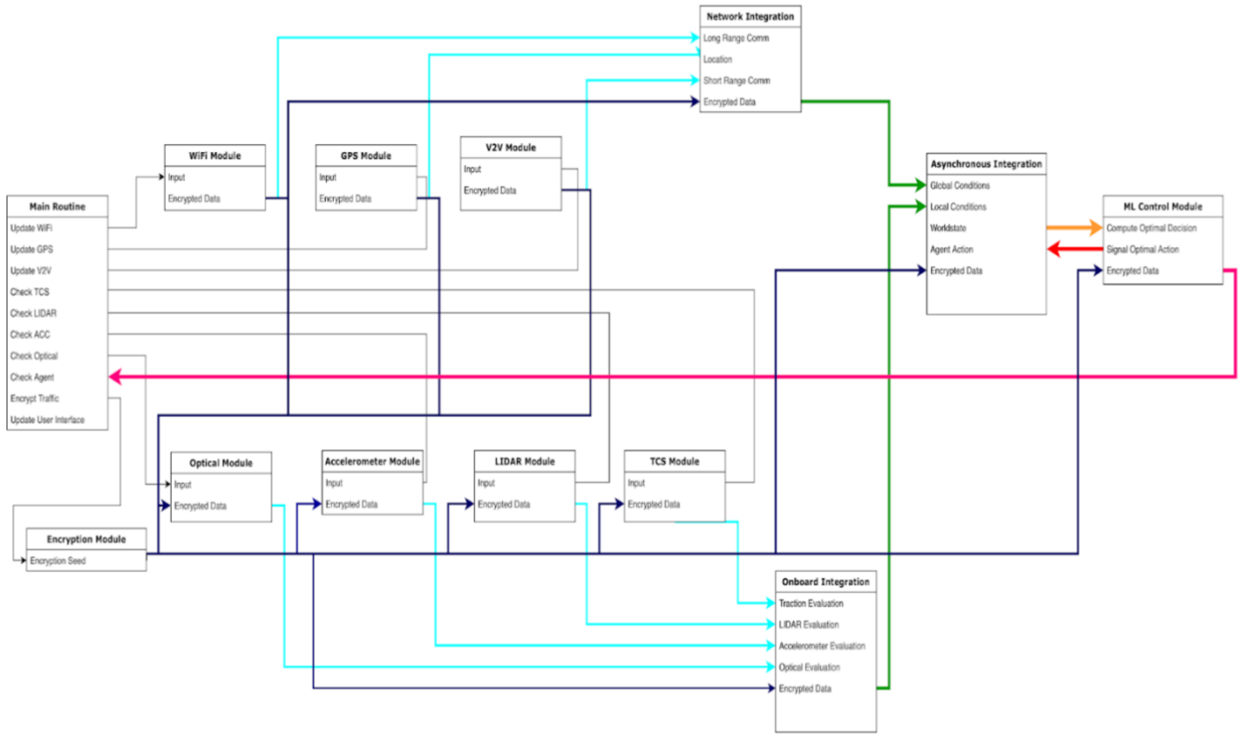
HW Drawing:



SW Drawing:



Critical path during development will be: Develop hardware control modules >> Develop route planning algorithm >> develop ML control algorithm >> Develop network control modules

This is because testing of these modules depends on the previous modules being completed.

Resource Breakdown Structure

1. Integrate sensor information from multiple sources into a consistent perception.
    1. Networking technologies to communicate between systems
        1. S GPS Module for long range route planning
            1. GPS Module often to avoid traffic along the route
            2. System shall consider GPS position when within 15 meters of SLAM estimation
            3. System shall alert network when GPS position is unreliable
        2. System shall use V2V Module for short range communication
            1. System shall communicate rangefinding information through V2V
            2. System shall alert nearby vehicles of rapid changes in traffic conditions
            3. System shall communicate GPS and WiFi data as needed
        3. System shall use WiFi Module for global communication
            1. System shall utilize cell data technologies to communicate information of varying resolution.
                1. High resolution maps and accurate position require at least 4G LTE internet connection
                2. System shall be able to provide low resolution maps and coarse position over 2G internet or better
    2. System shall use on-board sensors to maintain safe operation
        1. System shall use Ultrasonic Sensors:
            1. System shall utilize Ultrasonic sensors to detect obstructions on route
            2. System shall have sensors at 12 distinct locations on the vehicle
            3. System shall asynchronously update perception system

2. System shall use manufacturer provided sensors
    1. System shall use Blind Spot Monitoring as specified by manufacturer
    2. System shall use Automatic Emergency Braking as specified by manufacturer
    3. System shall use Lane Departure Warning as specified by manufacturer
    4. System shall use Brake Assist as specified by manufacturer
    5. System shall use Forward Collision Warning as specified by manufacturer
    6. System shall use TCS as specified by manufacturer
    7. System shall use Wireless Battery Management System as specified by manufacturer
3. System shall use LIDAR Module as basis for environment map
    1. System shall typically update environment at a rate of 10 Hz
    2. System shall be able to increase refresh rate to 15 Hz as needed
    3. System shall utilize HDL-64E lasers
    4. System shall reliably detect potholes
    5. System shall detect objects in vehicle path
4. System shall use Optical Module to classify objects
    1. Objects shall be detected through edge detection and color shading
    2. Objects shall be classified as dynamic or static
    3. Objects classified as static shall be treated as landmarks by SLAM
    4. Objects classified as dynamic shall have simulated preference
    5. Dynamic obstructions shall be given maximum right of way based on simulated preferences
5. System shall use Accelerometer Module to determine vehicle momentum

            1. System shall restrict vehicle inputs to maintain acceptable G forces
            2. System shall vary strictness based on ambient conditions
            3. System shall set limits on vehicle input to maintain traction
        6. System shall use TCS Module to determine vehicle traction
            1. System shall prevent loss of traction through preemptive action
    3. System shall use hardware encryption to resist malicious interference
        1. Each hardware module shall have unique identification
        2. System shall provide periodically changing identifying information to network
            1. Server expects system to provide identification based on factory set identity
            2. Change in identity over time computed anonymously to trace vehicles after incidents.
            3. Change in identity prevents active monitoring except from automated and encrypted servers
2. System shall compute optimal decision based on perceptions
    1. System shall make every decision within 500 mS of data collection and will collect at least 100 mS of data before acknowledging an unexpected change of conditions.
    2. System shall classify objects by observed behavior and utilize such classifications to expedite decision making
    3. System shall integrate object classifications from networked systems
        1. System shall gather object data through v2v module
        2. System shall gather object data through short range optical module
        3. System shall gather object data through IEEE 802.11 module
        4. System shall gather object data through cellular module
3. System should share data on the back-end.
    1. System shall share the data to the servers at the back-end.

   2. System shall fetch the data from the servers specific to the route for smooth ride.
   3. System shall share the data with neighboring systems securely.
   4. System shall use all available network protocols to maintain high speed communication with servers

4. System shall use Wireless Data Network:

   1. System shall use the Dedicated Short Range Communication (DSRC):

      1. System shall use the Bluetooth technology for communication:

         1. System shall pair with approved devices to perform voice recognition

         2. System shall be able to pair with multiple devices

      2. System shall use Wi-Fi Enabled in-car telematics systems:

         1. WiFi network shall be a mesh of WiFi enabled devices

            1. System shall quickly communicate with WiFi systems

               1. System shall connect with stationary hubs and anticipate disconnections based on location

               2. System shall connect with other autonomous vehicles and transmit useful perceptual information

            2. System shall have anonymized and secure identity

               1. System shall utilize public-private key encryption

               2. System shall have a unique private key

               3. System shall make and track a new public key for each interaction

               4. System shall create a new key based on selected public key and other system's public key

      3. System shall use Wireless Router for Mobile hotspots:

         1. System shall accept route adjustments from authenticated user

         2. System shall provide high speed internet access to attached devices without detriment to autonomous driving network

      4. System shall use Short-range Optical Network:

         1. System shall quickly communicate with Optical Network

            1. System shall connect with stationary hubs and anticipate disconnections based on location

            2. System shall connect with other autonomous vehicles and transmit useful perceptual information

        2. System shall have anonymized and secure identity

            1. System shall utilize public-private key encryption

            2. System shall have a private key unique to optical module

            3. System shall make and track a new public key for each interaction

            4. System shall create a new key based on selected public key and other system's public key

    5. System shall use Connected Vehicle system with Network:

        1. System shall quickly communicate with V2V Network

            1. System shall connect with stationary hubs and anticipate disconnections based on location

            2. System shall connect with other autonomous vehicles and transmit useful perceptual information

        2. System shall have anonymized and secure identity

            1. System shall utilize public-private key encryption

            2. System shall have a private key unique to V2V module

            3. System shall make and track a new public key for each interaction

            4. System shall create a new key based on selected public key and other system's public key

    6. System shall use In vehicle Satellite Internet Connectivity:

        1. System shall utilize Cellular Protocols to communicate with Cell towers and Satellites

        2. System shall utilize WiFi mesh network to aggregate and transmit vehicle pose to central servers through Satellite Internet

5. System shall use Decision Making:

    1. System shall use Self-Localization Technology:
    2. System shall use Surrounding perception technology:
    3. System shall use Trajectory planning technology:
    4. System shall use Route Planning:
    5. System shall use Travel Plan
    6. System shall use Trajectory Optimization:
6. System shall use Cyber Security in Autonomous Vehicle System:
    1. System shall use Cyber-Physical System:
        1. System shall use Operational Technology Systems:
        2. System shall use Automated Vehicle System security issues:
        3. System shall use Control Area Network:
        4. System shall use Security System Design:
    2. System shall use Technical Design Decisions:
        1. System shall use Hypothesis of security system in Autonomous Vehicle:
    3. System shall use Traditional Standard Security Policies:
        1. System shall use Adversarial Model:
        2. System shall use Attack objective:
        3. System shall use Communication capability:
        4. System shall use Computing capability:
    4. System shall use Infrastructure and Security Mechanisms:
        1. System shall use Infrastructure for trust management:
        2. System shall use Secure Routing Protocol:
        3. System shall use Heterogeneous Network Integration:
        4. System shall use Secured Resources:
        5. System shall use Trust Identification:

5. System shall use System Security Design for the Autonomous vehicles:
6. System shall use Designing and Operational Model:
    1. System shall use Sensing:
    2. System shall use Decision:
    3. System shall use Integrity:
    4. System shall use Confidentiality:
7. System shall use Security Management:
    1. System shall use The prominent methods in understanding the security management of the vehicle system:
    2. System shall use Attack Tree Analysis:
    3. System shall use Software Vulnerability Analysis:
8. System shall use Security Testing Methods:
    1. System shall use Penetration Testing:
    2. System shall use Red Teaming Testing:
    3. System shall use Fuzz Testing:
    4. System shall use Network Testing:

7. System Shall use Machine Learning Algorithms in Autonomous Vehicles:

7.1 System Shall use Vehicle understanding and Learning methods:

7.1.1 System Shall use Unsupervised Learning of Vehicular System:

7.1.2 System Shall use Reinforcement Learning of the Vehicle system:

7.2 System Shall use Supervised Learning of Vehicular System:

7.2.1 System Shall use Artificial Neural Networks used by autonomous Vehicle System:

7.2.2 System Shall use Activation Functions which help vehicle learn from the input data:

7.2.3 System Shall use Sigmoid

7.2.4 System Shall use Hyperbolic Tangent:

7.2.5 System Shall use ReLu:

7.2.6 System Shall use SoftPlus:

7.3 System Shall use Training the artificial intelligent system in the vehicle system:

7.3.1 System Shall use Loss functions enabling the vehicle system to learn:

7.3.1.1System Shall use Mean Squared Error:

7.3.1.2 System Shall use Mean Absolute Error:

7.3.1.3 System Shall use Cross Entropy:

7.3.1.3 System Shall use Hinge:

7.4 System Shall use Data Preprocessing by the vehicle systems:

7.4.1 System Shall use Deep Neural Networks enabling the Vehicle system to learn:

7.4.2 System Shall use Convolution Neural Networks enabling the Vehicle system to learn:

7.4.3 System Shall use Structure of a convolutional neural network in vehicle systems:

7.4.3.1 System Shall use Convolution Layers:

7.4.3.2 System Shall use Pooling Layers:

7.4.3.3 System Shall use Algorithms enabling the Vehicle system to learn the patterns:

7.4.3.4System Shall use One Stage Networks:

7.4.3.5 System Shall use Decision Matrix Algorithm:

7.5 System Shall use Breakdown structure of the decision matrix algorithm:

7.6 System Shall use Composition of Decision Matrix Algorithm:

7.6.1 System Shall use AdaBoosting:

7.6.2 System Shall use Adaboosting resolves the problem of overfitting:

7.6.4 System Shall use Concept of Multiple iterations in decision making or classifying:

7.6.5 System Shall use Clustering Algorithms:

7.6.5.1 System Shall use Functionality of the Clustering algorithm in object detection:

7.6.5.2 System Shall use K-means Clustering Algorithm:

7.6.5.3 System Shall use Pattern Recognition Algorithm:

7.6.5.4 System Shall use Support Vector Machines:

7.6.5.5 System Shall use Regression Algorithms:

7.6.5.6 System Shall use Shape of the regression lines:

7.7 System Shall use Various of dependent variables and samples of sensors raw data collected:

7.8 System Shall use Number of independent variables:

7.9 System Shall use Yolo Algorithm:

7.10 System Shall use Image Classification with Localization by the vehicle system

7.11 System Shall use Object Detection for the vehicle system

7.12 System Shall use Two Stage Networks

7.13 System shall use Faster R-CNN

Executive Summary

Specialists in the field anticipated that by 2030, automated driving will be sufficiently reliable to replace the traditional driving technique that humans have been a straight part of. It would open a whole new set of possibilities including but not limiting to affordability, providing huge savings and benefits. However on the other hand, there are valid reasons to have a concern. As the nature of industry always goes on to highlight the positive side of the blooming technology which overshadows the possible troubles or the critical situations which can arise. Along with that, they tend to ignore critical impediments to autonomous vehicle development and exaggerate future benefits to maximize the profits.

The volatile persona of technology outlays the uncertainty in the advantages and costs, travel effects, and demand. A huge leap of progress is required before autonomous vehicles can be brought into the commercialized space where it is expected to undergo uncalled circumstances like high volume traffic, weather conditions, unpaved roads, diminished lanes and break out of the internet. A single error in decision making of autonomous vehicles can cause threat to a life or more. So a rigorous testing will be required before launching these vehicles in the market, otherwise if not functioned as expected it may create the fear of illusion in the market for the future autonomous vehicles. The initial models for the commercial audience are highly likely to be expensive and limited in performance. They will bring newer risks and costs which will limit the sales as to why a customer would be willing to pay a 60-80% increment in the cost of a vehicle which is not fully ready.

Introduction

Building a mechanized vehicle with an independent driving framework is especially testing because of rigid execution prerequisites as far as both creating the safe operational choices and completing the process of handling at constant. Architecting self-sufficient driving frameworks is especially trying for a few reasons. These frameworks must make the "right" operational choice consistently to maintain a strategic distance from mishaps, in this way progressed AI, PC vision and mechanical preparing calculations, normally computationally concentrated, are utilized to convey the necessary high accuracy. In spite of the enormous measure of calculation, it is basic for such a strategic framework to have the option to respond to the basic condition at ongoing, which implies the handling in every case needs to be completed at exacting cutoff times. Besides, the framework needs to play out the essential calculation under certain force financial plans to avoid adversely affecting the driving extent and eco-friendliness of the vehicle by huge sums.

Level of Automation: These vehicles require a broad range of technologies and infrastructures to operate properly. Each vehicle is required to continuously collect and interpret vast amounts of information. Every system of the car must work with the surrounding environment, and technological advancements must be made to ensure autonomous vehicles work within several context

As technology advances, our roads are being shared with automated vehicles that utilize a varying degree of technologies and applications. Different technologies allow for a wide range of automation for vehicles. These levels of automation describe various elements and capabilities of the vehicles as they pertain to driving automation. The five levels of automated vehicles represent capabilities and options for drivers.

No Automation: Cars that always need driver input; there is no level of automation

Driver Assistance: Vehicles that have some driving mode-specific automation, such as steering or acceleration/deceleration help. Drivers must perform driving tasks, but the technology is there to assist the drivers. help with warnings and alerts. Many US states consider this to be the last-level of 'non-automation'.

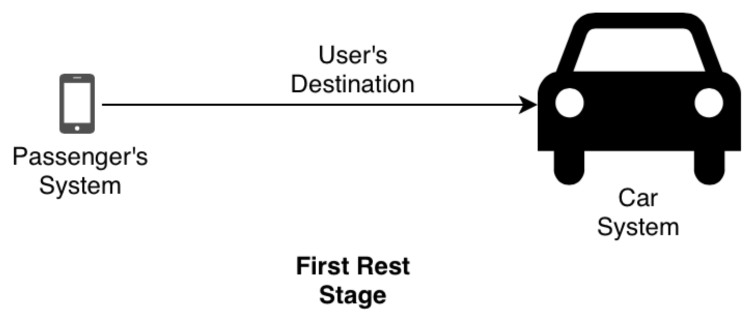
Partial Automation: Driver Assistance technologies, cars will use information around them to assist drivers in real-time, and help the driver with some dynamic driving task. They still have to react, but the US states consider these vehicles to be the first level of automated driving technology.

Conditional Automation: The vehicle monitors the driving environment, and performance modes allow decisions to be made based on the current conditions, though the drive can still intervene.

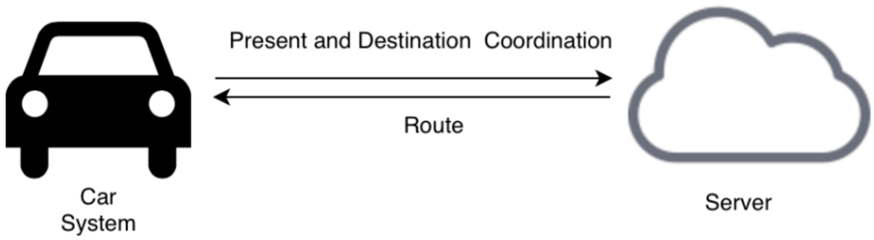
High Automation: The vehicle can take action in all aspects of dynamic driving, even without driver response.

Full Automation: The top level of vehicle automation. A human doesn’t need to be there or give any directions. It can respond to all road conditions.

Data Flow Diagrams

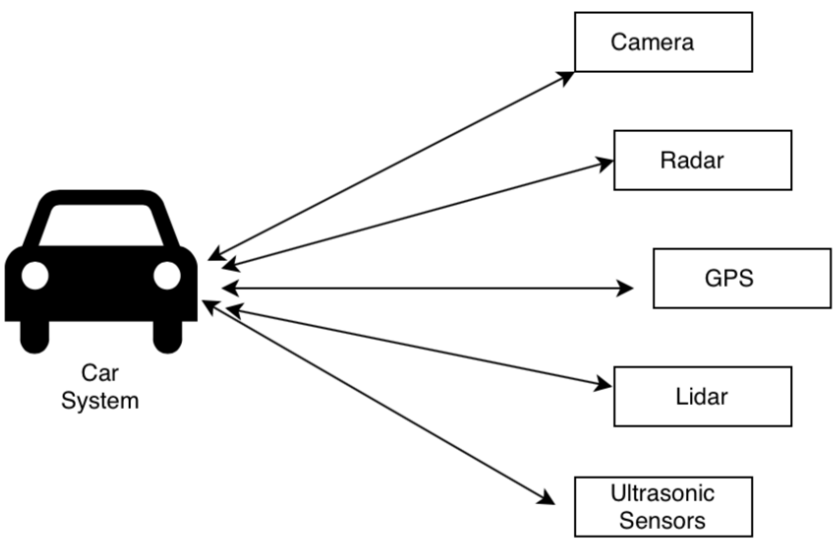


When the passenger connects with the car using the smartphone or car’s inbuilt system, the data comprising the coordination of the destination, flows from the smartphone to car system.



Second Rest Stage

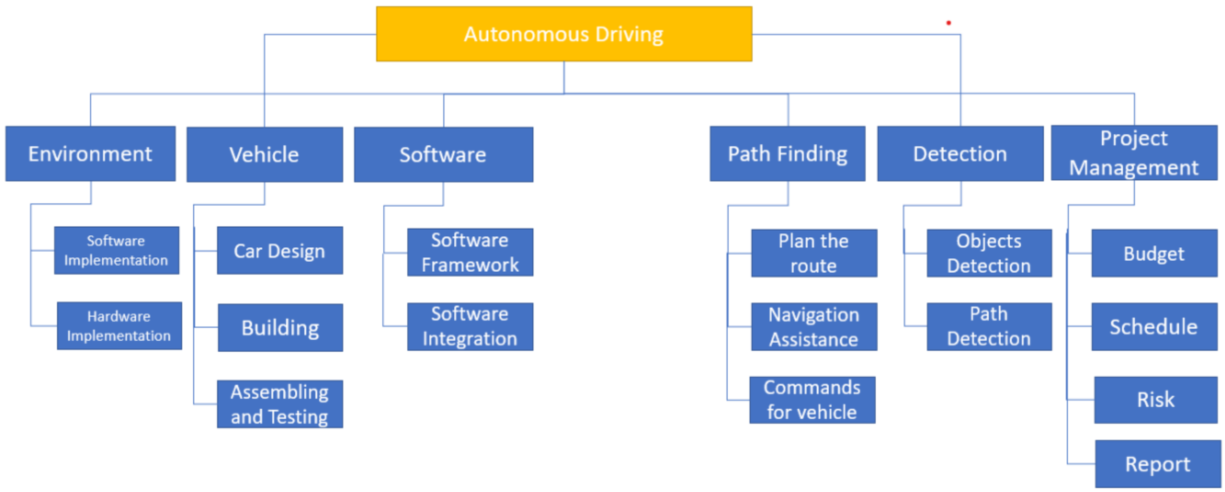
The car system connected to the server with present and destination coordination. Server processes it and sends back the possible route information to the car system where the user can have a visual of the routes. Here the server sends the default fastest route and passengers have the flexibility to choose other routes.



Drive Stage

With the route data, the car starts with collecting the data from the camera, radar, GPS, Lidar and ultrasonic sensors. This data is processed locally, and the collective is shared with the server for enhanced navigation and smooth driving.

Work Breakdown Structure:



Resource & Time Estimation:

1. Sensor information from multiple sources

1.1 Working technologies to communicate between systems

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Usage of Route planning and find the optimal route	1.1.1	-	1.1.1.1	Software Engineer Network Engineer Mechanical Engineer	1 1 1	2 Weeks	
Traffic detection and analysis of best route	1.1.1.1	1.1.1	1.1.1.2	Software Engineer Network Engineer	1 1	2 Weeks	

Positioning of the vehicle for the travelling	**1.1.1.2**	**1.1.1.1**	**1.1.1.3**	**Software Engineer** **Software Engineer (Lead)** **Software Engineer**	**1** **1** **1**	**2 Weeks**	
Taking inputs from network and enabling the alert system	**1.1.1.3**	**1.1.1.2**	**1.1.2**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	
Alerting system usage for unreachable network	**1.1.1.3**	**1.1.1.2**	**1.1.2**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	
Vehicular communication to avoid collisions	**1.1.2**	**1.1.1.3**	**1.1.2.1**	**Software Engineer** **Network Engineer** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Using the V2V module for short range communication	**1.1.2**	**1.1.1.3**	**1.1.2.1**	**Software Engineer** **Network Engineer** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Using the V2V module and finding the range limits	**1.1.2.1**	**1.1.2**	**1.1.2.2**	**Software Engineer** **Network Engineer** **Telecommunication Engineer**	**1** **1** **1**	**1 Weeks**	

Using the V2V communication alert the vehicles on the path	**1.1.2.2**	**1.1.2.1**	**1.1.2.3**	**Software Engineer** **Network Engineer**	**1** **1**	**1 Weeks**	
Communication with other vehicles for traffic detection	**1.1.2.3**	**1.1.2.2**	**1.1.3**	**Telecommunication Engineer**	**1**	**2 Weeks**	
Usage of GPS positioning and WiFi module for the positioning and connection to the network	**1.1.3**	**1.1.2.3**	**1.1.3.1**	**Software Engineer** **Network Engineer** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Usage of WiFi module for the communication	**1.1.3**	**1.1.2.3**	**1.1.3.1**	**Software Engineer** **Network Engineer** **Telecommunication Engineer**	**1** **1** **1**	**1 Weeks**	
Usage of WiFi module for the sake of communication with vehicles	**1.1.3**	**1.1.2.3**	**1.1.3.1**	**Software Engineer** **Network Engineer** **Telecommunication Engineer**	**1** **1** **1**	**1 Weeks**	
Usage of WiFi module for the sake of communication with the nodes in the network	**1.1.3.1**	**1.1.3**	**1.1.3.1.1**	**Network Engineer** **Telecommunication Engineer**	**1** **1**	**2 Weeks**	

Usage of cellular data for the better communication	**1.1.3.1**	**1.1.3**	**1.1.3.1.1**	**Network Engineer** **Telecommunication Engineer**	**1** **1**	**2 Weeks**	
Usage of cellular data for the sake of 2D maps	**1.1.3.1**	**1.1.3**	**1.1.3.1.1**	**Network Engineer** **Telecommunication Engineer**	**1** **1**	**1 Weeks**	
Usage of cellular data for the sake of accurate positioning	**1.1.3.1.1**	**1.1.3.1**	**1.1.3.1.2**	**Hardware Engineer** **Software Engineer** **Network Engineer**	**1** **1** **1**	**1 Weeks**	
Usage of cellular data for the sake of high-speed internet connectivity to the network	**1.1.3.1.1**	**1.1.3.1**	**1.1.3.1.2**	**Hardware Engineer** **Software Engineer** **Network Engineer**	**1** **1** **1**	**2 Weeks**	
Usage High resolution maps and accurate position require least 4G LTE	**1.1.3.1.1**	**1.1.3.1**	**1.1.3.1.2**	**Hardware Engineer** **Software Engineer** **Network Engineer**	**1** **1** **1**	**1 Weeks**	
Usage Low resolution maps and coarse position over 2G internet	**1.1.3.1.2**	**1.1.3.1.1**		**Hardware Engineer** **Software Engineer** **Network Engineer**	**1** **1** **1**	**1 Weeks**	

1.2

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Usage of ultrasonic sensors for the object detection	**1.2.1**	**1.2.1.1**	**1.2.1.1**	**Electrical Engineer**	**1**	**1 Weeks**	
Enabling Ultrasonic sensors to detect obstructions on route	**1.2.1.1**	**1.2.1**	**1.2.1.2**	**Electrical Engineer**	**1**	**1 Weeks**	
Usage of sensors at 12 distinct locations on the vehicle	**1.2.1.2**	**1.2.1.1**	**1.2.1.3**	**Electrical Engineer**	**1**	**1 Weeks**	
Usage of sensors at 12 distinct for helping the vehicle to understand the position	**1.2.1.2**	**1.2.1.1**	**1.2.1.3**	**Electrical Engineer**	**1**	**1 Weeks**	
Usage of sensors Asynchronously update perception system	**1.2.1.3**	**1.2.1.2**	**1.2.2**	**Software Engineer**	1	**1 Weeks**	

Usage of the Manufacturer provided sensors	**1.2.2**	**1.2.1.3**	**1.2.2.1**	**Software Engineer** **Electrical Engineer** **Mechanical Engineer**	**1** **1** **1**	**1 Weeks**	
Usage of sensors for Blind Spot Monitoring by the vehicle	**1.2.2.1**	**1.2.2**	**1.2.2.2**	**Software Engineer** **Automobile Engineer**	**1** **1**	**1 Weeks**	
Enabling the Emergency Braking system	**1.2.2.1**	**1.2.2**	**1.2.2.2**	**Software Engineer** **Automobile Engineer**	**1** **1**	**1 Weeks**	
Usage automatic Emergency Braking for collision avoidance	**1.2.2.2**	**1.2.2.1**	**1.2.2.3**	**Software Engineer** **Electrical Engineer** **Mechanical Engineer**	**1** **1** **1**	**1 Weeks**	
Usage of sensors for lane detections	**1.2.2.3**	**1.2.2.2**	**1.2.2.4**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	
Usage of the lane Departure Warning for better driving	**1.2.2.3**	**1.2.2.2**	**1.2.2.4**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	

Usage of break assisting technology for better riding on vehicle	**1.2.2.3**	**1.2.2.2**	**1.2.2.4**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	
Usage of brake assist in case of emergency	**1.2.2.4**	**1.2.2.3**	**1.2.2.5**	**Mechanical Engineer** **Automobile Engineer**	**1** **1**	**1 Weeks**	
Enabling the forward collision warning system with the help of sensor data	**1.2.2.5**	**1.2.2.4**	**1.2.2.6**	**Software Engineer** **Software Engineer (Lead)** **Mechanical Engineer** **Automobile Engineer**	**1** **1** 1 1	**1 Weeks**	
Usage of forward collision warning for preventing mishaps	**1.2.2.5**	**1.2.2.4**	**1.2.2.6**	**Software Engineer** **Software Engineer (Lead)** **Mechanical Engineer** **Automobile Engineer**	**1** **1** 1 1	**1 Weeks**	
Usage of TCS module for the map detection	**1.2.2.6**	**1.2.2.5**	**1.2.2.7**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	
Usage of wireless battery for avoiding the space mismanagem ent	**1.2.2.7**	**1.2.2.6**	**1.2.3**	**Software Engineer (Lead)** **Mechanical Engineer**	**1** **1**	**1 Weeks**	

				Electrical Engineer	1		
Usage Wireless Battery Management System for energy of the vehicle	**1.2.2.7**	**1.2.2.6**	**1.2.3**	**Software Engineer (Lead)** **Mechanical Engineer** **Electrical Engineer**	**1** **1** 1	**2 Weeks**	
Usage of Lidar module for ranging and detection	**1.2.3**	**1.2.2.7**	**1.2.3.1**	**Software Engineer (Lead)** **Mechanical Engineer** **Telecommunication Engineer**	**1** **1** 1	**2 Weeks**	
Enabling Lidar module in vehicle for better understanding of environment by the vehicle	**1.2.3**	**1.2.2.7**	**1.2.3.1**	**Software Engineer (Lead)** **Mechanical Engineer** **Telecommunication Engineer**	**1** **1** 1	**1 Weeks**	
Updating environment at a rate of 10 Hz	**1.2.3.1**	**1.2.3**	**1.2.3.2**	**Mechanical Engineer** **Telecommunication Engineer**	**1** **1**	**2 Weeks**	

Using the Increase refresh rate to 15 Hz for the better vision by the rider	**1.2.3.2**	**1.2.3.1**	**1.2.3.3**	**Mechanical Engineer** **Telecommunication Engineer**	**1** **1**	**2 Weeks**	
Usage of HDL-64E lasers for collision and accident avoidance	**1.2.3.3**	**1.2.3.2**	**1.2.3.4**	**Mechanical Engineer** **Telecommunication Engineer**	**1** **1**	**1 Weeks**	
Usage of HDL-64E lasers for the detection of potholes	**1.2.3.4**	**1.2.3.3**	**1.2.3.5**	**Mechanical Engineer** **Telecommunication Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Usage of HDL-64E lasers for detecting objects	**1.2.3.5**	**1.2.3.4**	**1.2.4**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**2 Weeks**	
Enabling the optical module for better classification	**1.2.4**	**1.2.3.5**	**1.2.4.1**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**1 Weeks**	

Usage of Optical Module to classify objects accurately	**1.2.4**	**1.2.3.5**	**1.2.4.1**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**2 Weeks**	
Usage of Optical Module and HDL-64E for the edge detection and color shading	**1.2.4.1**	**1.2.4**	**1.2.4.2**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer (Lead)**	**1** **1** **1**	**2 Weeks**	
Usage of Optical Module and HDL-64E for dynamic or static classification	**1.2.4.2**	**1.2.4.1**	**1.2.4.3**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer (Lead)**	**1** **1** **1**	**1 Weeks**	
SLAM detection for static shall be treated as landmarks	**1.2.4.3**	**1.2.4.2**	**1.2.4.41**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**1Weeks**	
SLAM detection for dynamic shall be treated as landmarks by simulated performance	**1.2.4.41**	**1.2.4.3**	**1.2.5**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**1 Weeks**	

Usage of by selecting stereo vision as a sensor, Maximum right of way based on simulated preferences	**1.2.5**	**1.2.4.41**	**1.2.5.11**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**1 Weeks**	
Usage of accelerometer Module to determine vehicle momentum	**1.2.5.11**	**1.2.5**	**1.2.5.1**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**2 Weeks**	
Usage Vehicle sensors inputs to maintain acceptable G forces	**1.2.5.1**	**1.2.5.11**	**1.2.5.2**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**1 Weeks**	
Usage Vehicle sensors inputs vary strictness based on ambient conditions	**1.2.5.2**	**1.2.5.1**	**1.2.5.3**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**1 Weeks**	
Usage Vehicle sensors inputs and set limits on vehicle input to maintain traction	**1.2.5.3**	**1.2.5.2**	**1.2.6**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**2 Weeks**	

Usage Vehicle sensors inputs and TCS Module to determine vehicle traction	**1.2.6**	**1.2.5.3**	**1.2.6.1**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer (Lead)**	**1** **1** **1**	**2 Weeks**	
Usage Vehicle sensors inputs and prevent loss of traction through preemptive action	**1.2.6.1**	**1.2.6**	**-**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer**	**1** **1** **1**	**2 Weeks**	

1.3 Hardware encryption to resist malicious interference

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Usage Vehicle sensors inputs for the unique identification	**1.3.1**	**-**	**1.3.2**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer (Lead)**	**1** **1** **1**	**2 Weeks**	

Usage Vehicle sensors inputs and periodically changing identifying information to network	**1.3.2**	**1.3.1**	**1.3.2.1**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Usage Vehicle sensors inputs provide identification based on factory set identity	**1.3.2.1**	**1.3.2**	**1.3.2.2**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**2 Weeks**	
Usage Vehicle sensors inputs time computed anonymously to trace vehicles after incidents.	**1.3.2.2**	**1.3.2.1**	**1.3.2.3**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**2 Weeks**	

Usage Vehicle sensors inputs and prevents active monitoring except from automated and encrypted servers	**1.3.2.3**	**1.3.2.2**	**-**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**2 Weeks**	

1. System shall compute optimal decision based on perceptions

2.1 Make every decision within 500 mS of data collection and will collect at least 100 mS of data before acknowledging an unexpected change of conditions.

2.2 Classify objects by observed behavior and utilize such classifications to expedite decision making.

2.3 Integrate object classifications from networked systems

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Usage of v2v module to gather object data through	**2.3.1**	**-**	**2.3.2**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	

Usage of v2v module and gather object data through short range optical module	**2.3.2**	**2.3.1**	**2.3.3**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Enabling the IEEE 802.11 module for the data gathering	**2.3.3**	**2.3.2**	**2.3.4**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Usage IEEE 802.11 module to gather object data	**2.3.3**	**2.3.2**	**2.3.4**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Enabling the cellular module in the vehicle	**2.3.3**	**2.3.2**	**2.3.4**	**Software Engineer** **Software Engineer (Lead)** **Machine Learning**	**1** **1** **1**	**2 Weeks**	

				Engineer Telecommunication Engineer	 1		
Usage of cellular module to gather object data	2.3.4	2.3.3	-	Software Engineer Software Engineer (Lead) Machine Learning Engineer Telecommunication Engineer	1 1 1 1	2 Weeks	

3. Backend Sharing

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Enabling the cluster environment for data storage	3.1	-	3.2	Software Engineer Software Engineer (Database Expertise) Machine Learning Engineer Telecommunication Engineer	1 1 1 1	2 Weeks	

Implementing the high-end file system in the cluster	**3.1**	**-**	**3.2**	**Software Engineer** **Software Engineer (Database Expertise)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Providing data replication and failsafe	**3.1**	**-**	**3.2**	**Software Engineer** **Software Engineer (Database Expertise)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Usage of network to share the data to the servers at the back-end.	**3.1**	**-**	**3.2**	**Software Engineer** **Software Engineer (Database Expertise)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	

Fetching the data from the servers specific to the route for smooth ride.	**3.2**	**3.1**	**3.3**	**Software Engineer** **Software Engineer (Database Expertise)** **Machine Learning Engineer** **Telecommunication Engineer**	**1** **1** **1** **1**	**2 Weeks**	
Sharing the data with neighboring systems securely using the secured protocols	**3.3**	**3.2**	**3.4**	**Software Engineer** **Software Engineer (Database Expertise)** **Machine Learning Engineer** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1** 1	**2 Weeks**	
Usage of all available network protocols to maintain high speed communication with servers	**3.4**	**3.3**	**-**	**Software Engineer** **Software Engineer (Database Expertise)** **Machine Learning Engineer** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1** 1	**2 Weeks**	

4.

4.1 Dedicated Short-Range Communication (DSRC):

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Usage Bluetooth technology for communication with the devices and vehicles	**4.1.1**	**-**	**4.1.1.1**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**2 Weeks**	
Enabling Pairing with multiple devices	**4.1.1.2**	**4.1.1.1**	**4.1.2**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**2 Weeks**	
Enabling the Wi-Fi in-car Telematics systems	**4.1.2**	**4.1.1.2**	**4.1.2.1**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Enabling Mesh topology of WiFi enabled devices	**4.1.2.1**	**4.1.2**	**4.1.2.1.1**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**1 Weeks**	
Usage of communication with WiFi systems	**4.1.2.1.1**	**4.1.2.1**	**4.1.2.1.1.1**	**Software Engineer** **Software Engineer (Lead)**	**1** **1**	**2 Weeks**	

Connecting with stationary hubs and anticipate disconnections based on location	**4.1.2.1.1.1**	**4.1.2.1.1**	**4.1.2.1.1.2**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**1 Weeks**	
Connecting with other autonomous vehicles and transmit useful perceptual information	**4.1.2.1.1.2**	**4.1.2.1.1.1**	**4.1.2.1.2**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Securing the identity by following strict protocols	**4.1.2.1.2**	**4.1.2.1.1.2**	**4.1.2.1.2.1**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**1 Weeks**	
Utilize public-private key encryption methods for data transfer	**4.1.2.1.2.1**	**4.1.2.1.2**	**4.1.2.1.2.2**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	

Usage of having the unique private key	**4.1.2.1.2.2**	**4.1.2.1.2.1**	**4.1.2.1.2.3**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**1 Weeks**	
Make and track a new public key for each interaction	**4.1.2.1.2.3**	**4.1.2.1.2.2**	**4.1.2.1.2.4**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Create a new key based on selected public key and other system's public key	**4.1.2.1.2.4**	**4.1.2.1.2.3**	**4.1.3**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	

Using Wireless Router for Mobile hotspots	**4.1.3**	**4.1.2.1.2.4**	**4.1.3.1**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Detection and accepting the route adjustments from authenticated user	**4.1.3.1**	**4.1.3**	**4.1.3.2**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Providing the high-speed internet access to attached devices without detriment to autonomous driving network	**4.1.3.2**	**4.1.3.1**	**4.1.4**	**Telecommunication Engineer** **Network Engineer** **Software Engineer** **Software Engineer (Lead)**	**1** **1** **1** **1**	**2 Weeks**	
Enabling the Optical Network for the short-range communication	**4.1.4**	**4.1.3.2**	**4.1.4.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	

Enabling the quick communication with Optical Network	**4.1.4.1**	**4.1.4**	**4.1.4.1.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Using automated method to connect with stationary hubs and anticipate disconnections based on location	**4.1.4.1.1**	**4.1.4.1**	**4.1.4.1.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Enabling the connection with other autonomous vehicles and transmit useful perceptual information	**4.1.4.1.2**	**4.1.4.1.1**	**4.1.4.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Securing the identity	**4.1.4.2**	**4.1.4.1.2**	**4.1.4.2.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	

Utilize public-private key encryption	**4.1.4.2.1**	**4.1.4.2**	**4.1.4.2.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Have a private key unique to optical module	**4.1.4.2.2**	**4.1.4.2.1**	**4.1.4.2.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Track a new public key for each interaction	**4.1.4.2.3**	**4.1.4.2.2**	**4.1.4.2.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Create a new key based on selected public key and other system’s public key	**4.1.4.2.4**	**4.1.4.2.3**	**4.1.5**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Connected Vehicle system with Network	**4.1.5**	**4.1.4.2.4**	**4.1.5.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1**	**2 Weeks**	

Enabling the Communicate with V2V Network	**4.1.5.1**	**4.1.5**	**4.1.5.1.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**2 Weeks**	
Enabling the connection with stationary hubs and anticipate disconnections based on location	**4.1.5.1.1**	**4.1.5.1**	**4.1.5.1.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1**	**2 Weeks**	
Enabling the connection with autonomous vehicles and transmit useful perceptual information	**4.1.5.1.2**	**4.1.5.1.1**	**4.1.5.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
Enabling the Anonymized and secure identity	**4.1.5.2**	**4.1.5.1.2**	**4.1.5.2.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1**	**2 Weeks**	

Generating the public-private key encryption method for data transfer	**4.1.5.2.1**	**4.1.5.2**	**4.1.5.2.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** 1	**2 Weeks**	
Generating a private key unique to V2V module communication	**4.1.5.2.2**	**4.1.5.2.1**	**4.1.5.2.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
Making and tracking a new public key for each interaction with the vehicles	**4.1.5.2.3**	**4.1.5.2.2**	**4.1.5.2.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	

Creating a new key based on selected public key and other system's public key	**4.1.5.2.4**	**4.1.5.2.3**	**4.1.6**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**1 Weeks**	
Enabling the in-vehicle Satellite Internet Connectivity	**4.1.6**	**4.1.5.2.4**	**4.1.6.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
Usage of the Cellular Protocols	**4.1.6.1**	**4.1.6**	**4.1.6.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**1 Weeks**	

Enabling the Cellular Protocols to communicate with Cell towers and Satellites	**4.1.6.1**	**4.1.6**	**4.1.6.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
Utilizing the WiFi mesh network to aggregate and transmit vehicle pose to central servers through Satellite Internet	**4.1.6.2**	**4.1.6.1**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**1 Weeks**	

5.

Functionality	**Functionality ID**	**Predecessor Functionality ID**	**Successor Functionality ID**	**Resource Designation**	**Resource Requirement**	**Duration**	**Workaround**
Enabling the self-localization technology with the sensor information	**5.1**	**-**	**5.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1**	**1 Weeks**	

Enabling the self-localization technology for the Surrounding perception	**5.2**	**5.1**	**5.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** **1**	**1 Weeks**	
Enabling the self-localization technology trajectory planning	**5.3**	**5.2**	**5.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** 1	**1 Weeks**	
Enabling the self-localization technology for the route Planning	**5.4**	**5.3**	**5.5**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** 1	**1 Weeks**	

Enabling the self-localization technology for travel planning design	**5.5**	**5.4**	**5.6**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** 1	**1 Weeks**	
Enabling the self-localization technology for the trajectory optimization	**5.6**	**5.5**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** 1	**1 Weeks**	

6.

6.1 Cyber-Physical System

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Enabling the Operational Technology Systems:	**6.1.1**	**-**	**6.1.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1** **1**	**1 Weeks**	

				Machine Learning Engineer			
Addressing the vehicle security issues	**6.1.2**	**6.1.1**	**6.1.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** 1	**1 Weeks**	
Vehicle security issues in the network	**6.1.3**	**6.1.2**	**6.1.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer**	**1** **1** **1** **1** 1	**3** **Weeks**	

Designing the Security System	**6.1.4**	**6.1.3**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** 1	**3** **Weeks**	

6.2 Technical Design Decisions

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Calculating the Hypothesis of security system in Autonomous Vehicle	**6.2.1**	**-**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** 1 1	**3** **Weeks**	

6.3 Traditional Standard Security Policies

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Design the Adversarial Model	**6.3.1**	**-**	**6.3.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** 1 1	**3 Weeks**	
Designing the Attack objective	**6.3.2**	**6.3.1**	**6.3.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1**	**4 Weeks**	
Enabling the and addressing the Communication capability issues	**6.3.3**	**6.3.2**	**6.3.4**	**Telecommunication Engineer** **Network Engineer**	**1** **1**	**3 Weeks**	

Enabling the and addressing the Communication computing issues	**6.3.4**	**6.3.3**	**-**	**Telecommunication Engineer** **Network Engineer**	**1** **1**	**4 Weeks**	

6.4

Functionality	**Functionality ID**	**Predecessor Functionality ID**	**Successor Functionality ID**	**Resource Designation**	**Resource Requirement**	**Duration**	**Workaround**
Designing Infrastructure for trust management	**6.4.1**	**-**	**6.4.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1**	**3** **Weeks**	
Designing the Secure Routing Protocols for secure communication	**6.4.2**	**6.4.1**	**6.4.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1**	**4 Weeks**	
Usage and enabling of Heterogeneous Network Integration	**6.4.3**	**6.4.2**	**6.4.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer**	**1** **1** **1**	**3** **Weeks**	

				Network Engineer	**1**		
Usage of the Secured Resources	**6.4.4**	**6.4.3**	**6.4.5**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer**	**1** **1** **1** **1**	**4 Weeks**	
Design the Trust Identification protocols for the security	**6.4.5**	**6.4.4**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** 1	**5 Weeks**	

6.5

6.6 Designing and Operational Model

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround

Designing the sensor detection protocol for better Sensing capabilities	**6.6.1**	**-**	**6.6.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**3 Weeks**	
Design the Decision making algorithms and make decisions	**6.6.2**	**6.6.1**	**6.6.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**4 Weeks**	
Designing the integrated system for the vehicle functioning	**6.6.3**	**6.6.2**	**6.6.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**5 Weeks**	

Improving the confidentiality of the vehicle system	**6.6.4**	**6.6.3**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** **1**	**4 Weeks**	

6.7

Functionality	**Functionality ID**	**Predecessor Functionality ID**	**Successor Functionality ID**	**Resource Designation**	**Resource Requirement**	**Duration**	**Workaround**
Using the various Algorithms	**6.7.1**	**-**	**6.7.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** 1	**3 Weeks**	
Attack Tree Analysis for decision making	**6.7.2**	**6.7.1**	**6.7.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** 1	**4 Weeks**	

Addressing the software Vulnerability issues and try to resolve them	**6.7.3**	**6.7.2**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1** 1	**5 Weeks**	

6.8

Functionality	**Functionality ID**	**Predecessor Functionality ID**	**Successor Functionality ID**	**Resource Designation**	**Resource Requirement**	**Duration**	**Workaround**
Understanding the issues related to Software Vulnerability and possible solutions	**6.8.1**	**-**	**6.8.2**	**Software Engineer (Quality Assurance)** **Software Engineer (Quality Assurance-Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1**	**3** **Weeks**	
Penetration Testing	**6.8.2**	**6.8.1**	**6.8.3**	**Software Engineer (Quality Assurance)** **Software Engineer (Quality Assurance-Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1**	**4 Weeks**	

Red Teaming Testing	**6.8.3**	**6.8.2**	**6.8.4**	**Software Engineer (Quality Assurance)** **Software Engineer (Quality Assurance-Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1**	**5 Weeks**	
Network Testing	**6.8.4**	**6.8.3**	**-**	**Software Engineer (Quality Assurance)** **Software Engineer (Quality Assurance-Lead)** **Telecommunication Engineer** **Network Engineer** **Project Manager**	**1** **1** **1** **1**	**4** Weeks	

7.

7.1 Vehicle understanding and Learning methods

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround

Unsupervised Learning of Vehicular System	**7.1.1**	**-**	**7.1.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**3** **Weeks**	
Reinforcement Learning of the Vehicle system	**7.1.2**	**7.1.1**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**4 Weeks**	
						5 Weeks	

7.2

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Artificial Neural Networks used by autonomous Vehicle	**7.2.1**	**-**	**7.2.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**3 Weeks**	
Activation Functions which help vehicle learn from the input data	**7.2.2**	**7.2.1**	**7.2.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**4 Weeks**	

Using the Sigmoid function as activation	**7.2.3**	**7.2.2**	**7.2.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**5 Weeks**	
Using the Hyperbolic Tangent function as activation	**7.2.4**	**7.2.3**	**7.2.5**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**3** **Weeks**	
Using the ReLu function as activation	**7.2.5**	**7.2.4**	**7.2.6**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**4 Weeks**	

Using the SoftPlus function as function.	**7.2.6**	**7.2.5**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**5 Weeks**	

7.3

7.3.1 Loss functions enabling the vehicle system to learn:

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Using the Mean Squared Error function for error analysis	**7.3.1.1**	**-**	**7.3.1.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**3** **Weeks**	

Using the Mean Absolute Error for error analysis	**7.3.1.2**	**7.3.1.1**	**7.3.1.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**4 Weeks**	
Using the Cross Entropy for finding the loss	**7.3.1.3**	**7.3.1.2**	**7.3.1.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**5 Weeks**	
Using the Hinge for finding the loss	**7.3.1.4**	**7.3.1.3**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**1 Weeks**	

7.4 Data Preprocessing by the vehicle systems

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
Deep Neural Networks enabling the Vehicle system to learn	**7.4.1**	**-**	**7.4.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**1 Weeks**	
Convolution Neural Networks enabling the Vehicle system to learn	**7.4.2**	**7.4.1**	**7.4.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**2 Weeks**	

Structure of a convolutional neural network in vehicle systems	**7.4.3**	**7.4.2**	**7.4.3.1**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**		
Convolution Layers	**7.4.3.1**	**7.4.3**	**7.4.3.2**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**1 Weeks**	
Pooling Layers	**7.4.3.2**	**7.4.3.1**	**7.4.3.3**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**2 Weeks**	

Algorithms enabling the Vehicle system to learn the patterns	**7.4.3.3**	**7.4.3.2**	**7.4.3.4**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**1 Weeks**	
One Stage Networks	**7.4.3.4**	**7.4.3.3**	**7.4.3.5**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**2 Weeks**	
Decision Matrix Algorithm	**7.4.3.5**	**7.4.3.4**	**-**	**Software Engineer** **Software Engineer (Lead)** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer** **Project Manager**	**1** **1** **1** **1** **1** **1**	**1 Weeks**	

7.5

7.6 Composition of Decision Matrix Algorithm

Functionality	Functionality ID	Predecessor Functionality ID	Successor Functionality ID	Resource Designation	Resource Requirement	Duration	Workaround
AdaBoosting	7.6.1	-	7.6.2	Software Engineer Telecommunication Engineer Network Engineer Machine Learning Engineer (Lead) Project Manager	1 1 1 1 1	1 Weeks	
Problem of overfitting	7.6.2	7.6.1	7.6.3	Software Engineer Telecommunication Engineer Network Engineer Machine Learning Engineer (Lead) Project Manager	1 1 1 1 1	2 Weeks	
Multiple iterations in decision making or classifying	7.6.3	7.6.2	7.6.4.1	Software Engineer Telecommunication Engineer Network Engineer Machine Learning Engineer (Lead) Project Manager	1 1 1 1 1	1 Weeks	

Clustering Algorithms	**7.6.4.1**	**7.6.3**	**7.6.4.2**	**Software Engineer** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer (Lead)** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
K-means Clustering Algorithm	**7.6.4.2**	**7.6.4.1**	**7.6.4.3**	**Software Engineer** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer (Lead)** **Project Manager**	**1** **1** **1** **1** **1**	**1 Weeks**	
Pattern Recognition Algorithm	**7.6.4.3**	**7.6.4.2**	**7.6.4.4**	**Software Engineer** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer (Lead)** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	

Support Vector Machines	**7.6.4.4**	**7.6.4.3**	**7.6.4.5**	**Software Engineer** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer (Lead)** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
Regression Algorithms	**7.6.4.5**	**7.6.4.4**	**7.6.4.6**	**Software Engineer** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer (Lead)** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	
Shape of the regression lines	**7.6.4.6**	**7.6.4.5**	**-**	**Software Engineer** **Telecommunication Engineer** **Network Engineer** **Machine Learning Engineer (Lead)** **Project Manager**	**1** **1** **1** **1** **1**	**2 Weeks**	

data collected

7.8 Number of independent variables:

7.9 Yolo Algorithm:

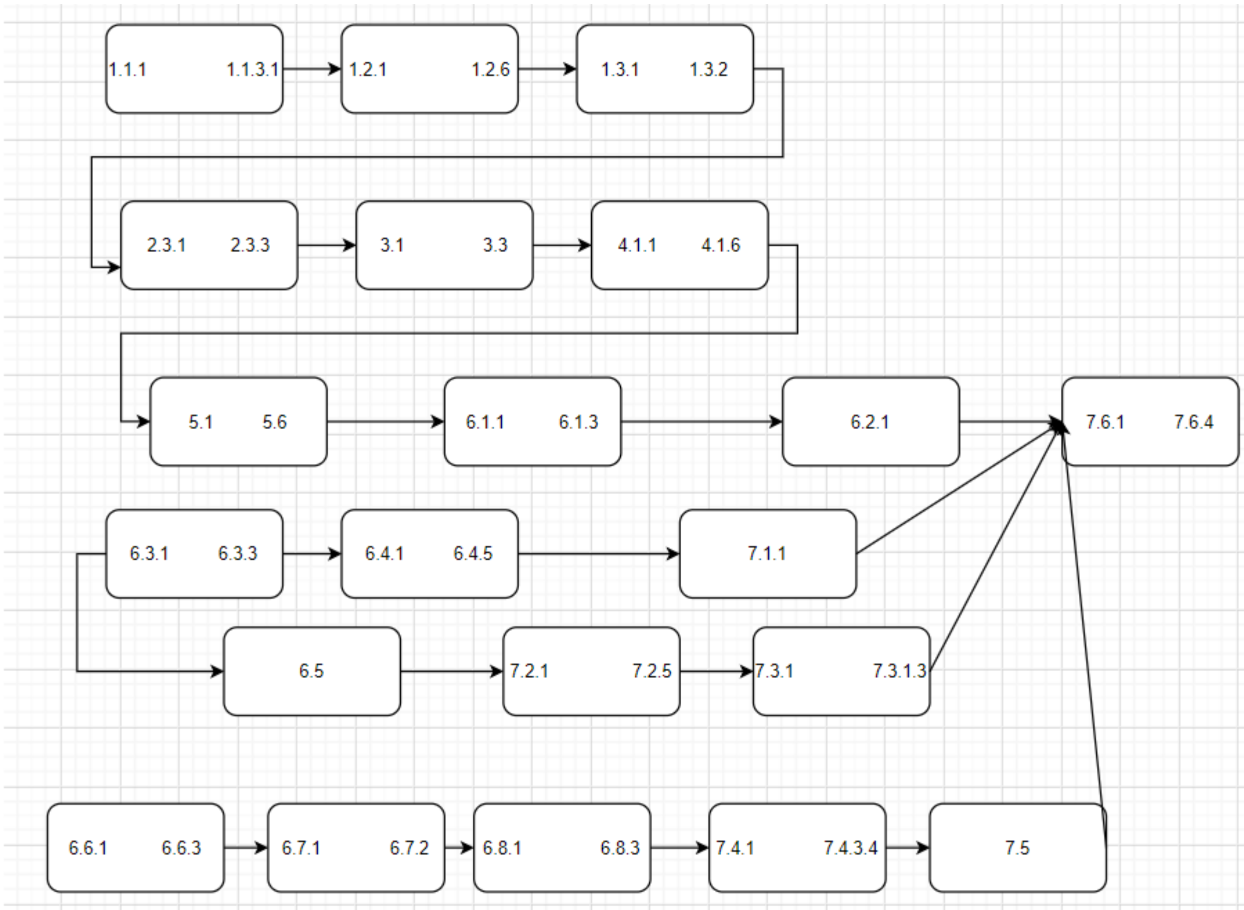
7.10 Image Classification with Localization by the vehicle system

7.11 Object Detection for the vehicle system

7.12 Two Stage Networks

7.13 Faster R-CNN

Network Diagram:



Critical Path - > 1.1.1 - 1.1.3.1 (8 Weeks) + 1.2.1 - 1.2.6 (12 Weeks) +1.3.1 -1.3.2 (4 Weeks) + 2.3.1 - 2.3.3 (6 Weeks) +2.3.1 - 2.3.3 (8 Weeks) +3.1 - 3.3 (8 Weeks)+ 4.1.1 - 4.1.6 (8 Weeks) + 5.1 - 5.6 (6 Weeks)+ 6.1.1 - 6.1.3 (2 Weeks) + 6.2.1 (4 Weeks) + 7.6.1 - 7.6.4 (4 Weeks) = **70 Weeks**

Risk Enumeration

Outcome Description	Risk	Probability (%)	Delay (weeks)	Risk Exposure
Key data could be corrupted due to software error.	Key Data Error	5	4	20
Software could have unacceptable performance and require refactoring.	Performance	8	4	32
Monitoring software may not register an unsafe condition.	Software vulnerability	5	4	20
Monitoring software may report a safe condition as unsafe.	Software vulnerability	5	2	10
There could be a delay in sourcing Hardware.	Hardware Procurement	6	2	12
Data reduction may take longer than expected.	Latency in data receiving	8	1	8
Difficult to use UI may require redesign	UI complexity	6	4	24
Processor memory may be insufficient and additional hardware may be required.	Processing time	1	2	2
Database management software may lose derived data.	Loss of Data	2	1	2
The machine learning algorithm may need replacement.	Machine Learning Algorithm	8	4	32

Expert consulting may be required.	Experts Decision	20	4	80
Hardware faults can be discovered during testing.	Faulty Hardware	10	2	20
Security vulnerability could be discovered and require patching.	Patching	30	2	60
Accuracy in the Machine Learning Model may require more time.	Machine Learning Algorithm	25	2	50
Accurate Trajectory Planning may require additional time	Processing time	25	1	25
Ensuring design complies with government regulation could take time.	Rules and Regulations	8	1	8
Delays may occur in developing the failover strategy of the Servers.	Failover Condition	6	2	12
Network Speed for Data transfer may be insufficient at desired frequency.	Network Latency	1	4	4
Replacing failed hardware may take time.	Hardware Error	10	4	40
Vehicle could be damaged during testing.	Physical Damage	8	1	8
Software updates may break functionality, requiring additional patching.	Patching	6	2	12

Risk Quantification:

Let the unit price be $75,000. The company aims to produce 100 vehicles every month and 1200 units every year. This is assuming the demand for our product is substantially lower than for a competitor. Thus, monthly revenue is 7.5 million dollars.

The critical path that we have calculated is around 16 months which is calculated to complete in 2 iterations.

If the project must face any trouble after 6 months then the major risk that the project would face would be in terms of the machine learning models accuracy and probability of it not reaching the expectations would be 50% as stated in the risk enumeration block.

There would be three options to be considered for the project to continue and achieve its goal. They are the following:

1. Continue as it is: If we the company has opted to continue without any changes then we have two sub branches:
   a) Probability of Success: 0.5 (Delay would be 6 months)
   b) Probability of Failure: 0.5 (Delay would be 6 months)
2. Try to reshuffle the star workforce: After reshuffling the work force we have two sub branches:
   a) Probability of Success: 0.6 (Delay would be 3 months)
   b) Probability of Failure: 0.4 (Delay would be 3 months)
3. Hire people from the consultancy: After hiring people from the consultancy we have two sub branches:
   a) Probability of Success: 0.8 (Delay would be 1 months)
   b) Probability of Failure: 0.2 (Delay would be 1 months)

Let us consider that the hiring cost from the consultancy would be around 50,000 $. Let the opportunity cost be 20%.

Cash Flow and NPV calculation at the beginning of the project:

Year 0: Cost = -7.5M*12 = -90M

Year 1: Revenue = 8M*9 = 72M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for starting the project = -90M + (72)/ (1.2) + 102/ (1.2*1.2) + 108/(1.2*1.2*1.2)

= 103.33M

Risk Tree Analysis:

Risk Tree: Branch 1 Continue as is

a) Sub Branch Success Criteria considered:

Year 0: Cost = -7.5M*12 = -90M

Year 1: Cost = -7.5M*6 = -45M, Revenue = 8M*3 = 24M, Total = -45 + 24 = -21M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for the project = -90M + (-21)/ (1.2) + 102/ (1.2*1.2) + 108/ (1.2*1.2*1.2)

= 25.83M

Loss = 103.33- (25.83) = 77.5M

b) Sub Branch Failure Criteria Considered:

Year 0: Cost = -7.5M*12 = -90M

Year 1: Cost = -7.5M*12 = -90M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for the project = -90M + (-90)/ (1.2) + 102/ (1.2*1.2) + 108/ (1.2*1.2*1.2)

= 31.66M

Loss = 103.33- (31.66) = 71.67M

Branch 1 Loss = 77.5M*0.5 + 71.67M*0.5

= 74.585M

Risk Tree: Branch 2 Reshuffle the workforce

a) Sub Branch Success Criteria considered:

Year 0: Cost = -7.5M*12 = -90M

Year 1: Cost = -7.5M*3 = -22.5M, Revenue = 8M*6 = 42M, Total = -22.5 + 42= -19.5M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for the project = -90M + (-19.5)/ (1.2) + 102/ (1.2*1.2) + 108/ (1.2*1.2*1.2)

= 27.083M

Loss = 103.33- (27.083) = 76.247M

b) Sub Branch Failure Criteria Considered:

Year 0: Cost = -7.5M*12 = -90M

Year 1: Cost = -7.5M*6 = -45M, Revenue = 8M*3 = 24M, Total = -45 + 24 = -21M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for the project = -90M + (-21)/ (1.2) + 102/ (1.2*1.2) + 108/ (1.2*1.2*1.2)

= 25.83M

Loss = 103.33- (25.83) = 77.5M

Branch 2 Loss = 76.247M*0.6 + 77.5*0.4

= 76.7482M

Risk Tree: Branch 3 Reshuffle the workforce

a) Sub Branch Success Criteria considered:

Year 0: Cost = -7.5M*12 – 0.05*9 = -90.45M

Year 1: Cost = -7.5M*1-0.05*1 = -7.55M, Revenue = 8M*8 = 42M, Total = -7.55 + 64= 56.45M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for the project = -90M + (56.45)/ (1.2) + 102/ (1.2*1.2) + 108/ (1.2*1.2*1.2)

= 89.925M

Loss = 103.33- (89.925) = 13.405M

b) Sub Branch Failure Criteria Considered:

Year 0: Cost = -7.5M*12 – 0.05*9 = -90.45M

Year 1: Cost = -7.5M*2-0.05*2 = -15.1M, Revenue = 8M*6 = 48M, Total = -7.55 + 48= 40.45M

Year 2: Revenue = 8.5M*12 = 102M

Year 3: Revenue = 9M*12 = 108M

The NPV for the project = -90M + (40.45)/ (1.2) + 102/ (1.2*1.2) + 108/ (1.2*1.2*1.2)

= 77.041M

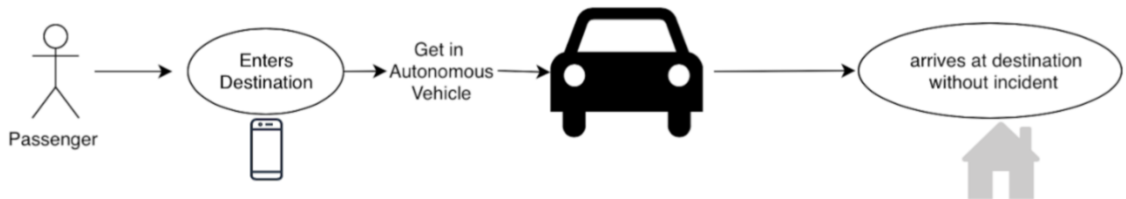
Loss = 103.33- (70.041M) = 26.28M

Branch 3 Loss = 13.405M*0.8 + 26.28M*0.2

= 15.98M

After the calculation of the 3 branch losses we can conclude that the Branch 3 can be considered for the project to recover. This can be considered because the loss calculated is the least out of the three branches.

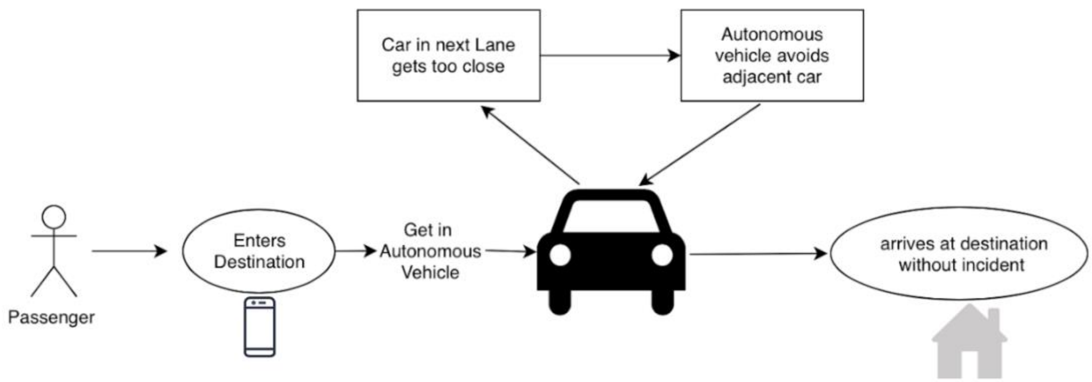
Use Cases:



Basic Use Case

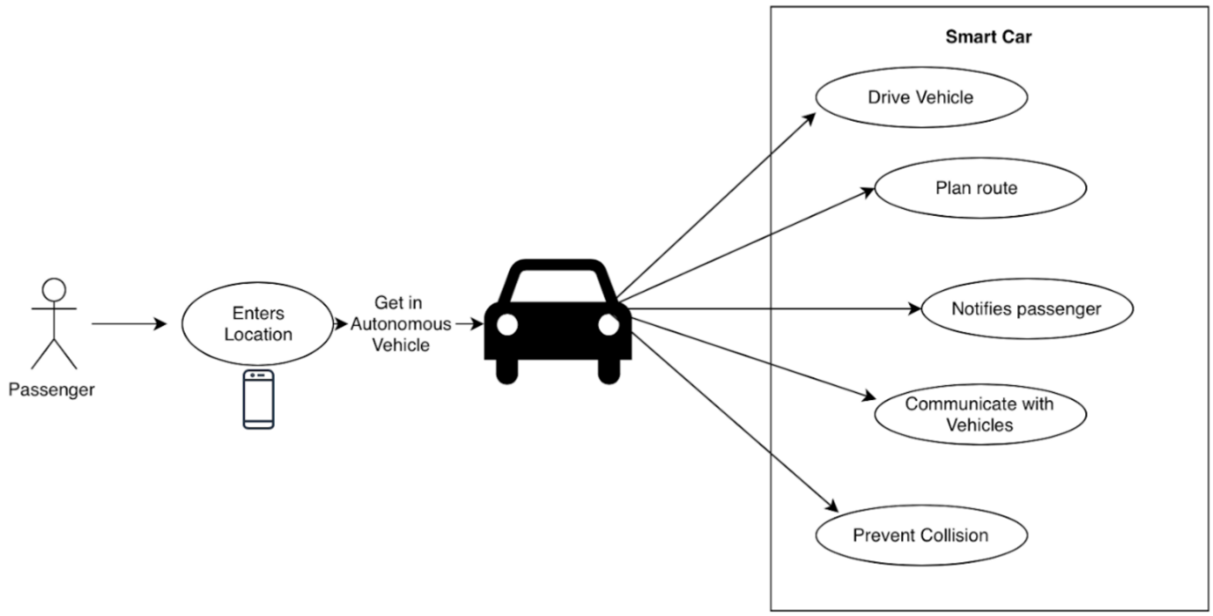
The user wishes to go to a destination B from current location A. They enter the address of B, and enter the autonomous vehicle, which is with the user at A. The user and autonomous vehicle get to destination B without any incident.

Collision Avoidance



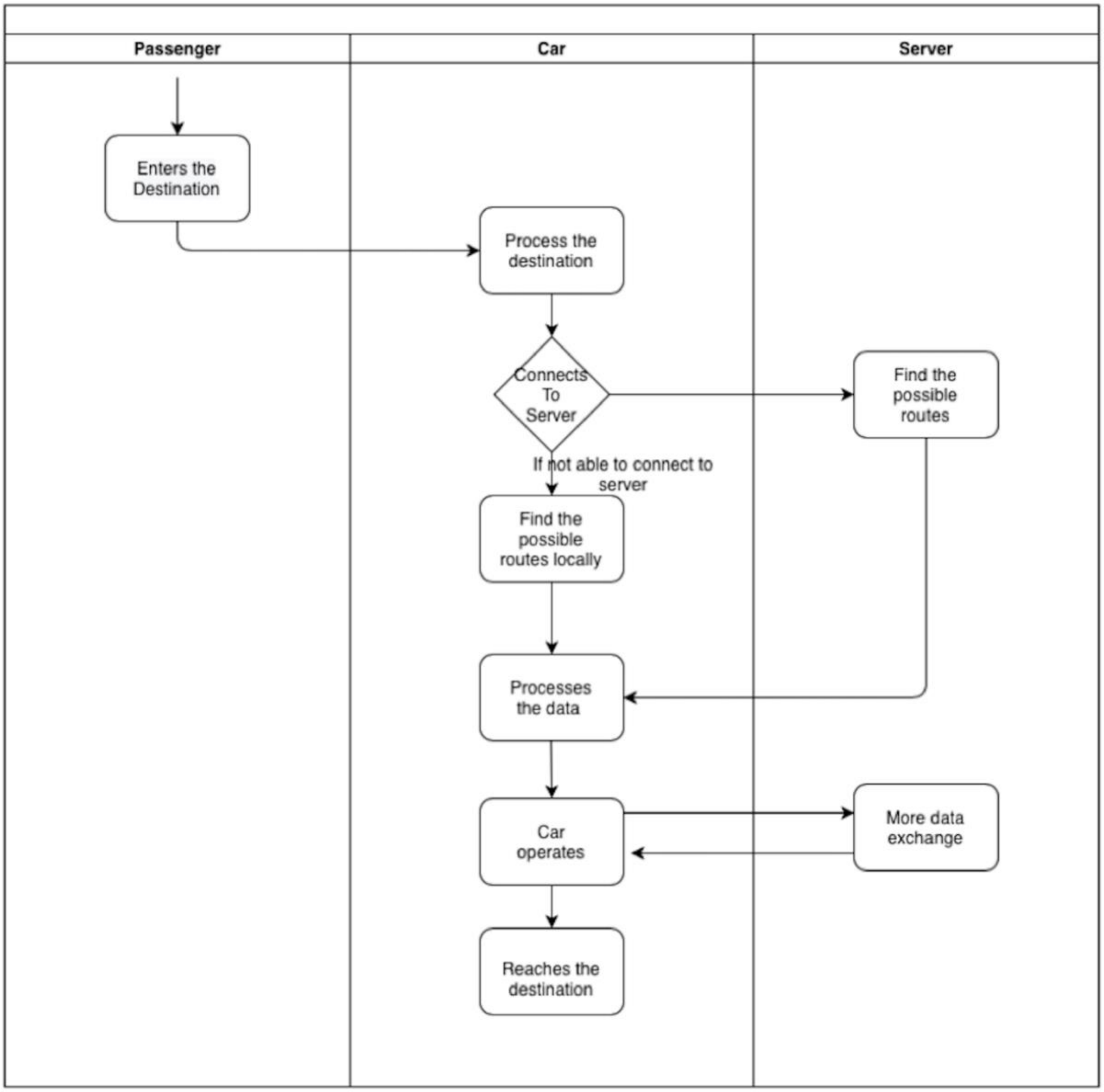
The user wishes to go to a destination B from current location A. They enter the address of B, and enter the autonomous vehicle, which is with the user at A. While on route to B, a separate, non-autonomous vehicle gets too close to the autonomous vehicle, threatening to crash into them. The autonomous vehicle reacts to its surroundings and avoids the collision. Finally, the user and autonomous vehicle get to destination B without further incident, and with no collision occurring.

Typical Use Case



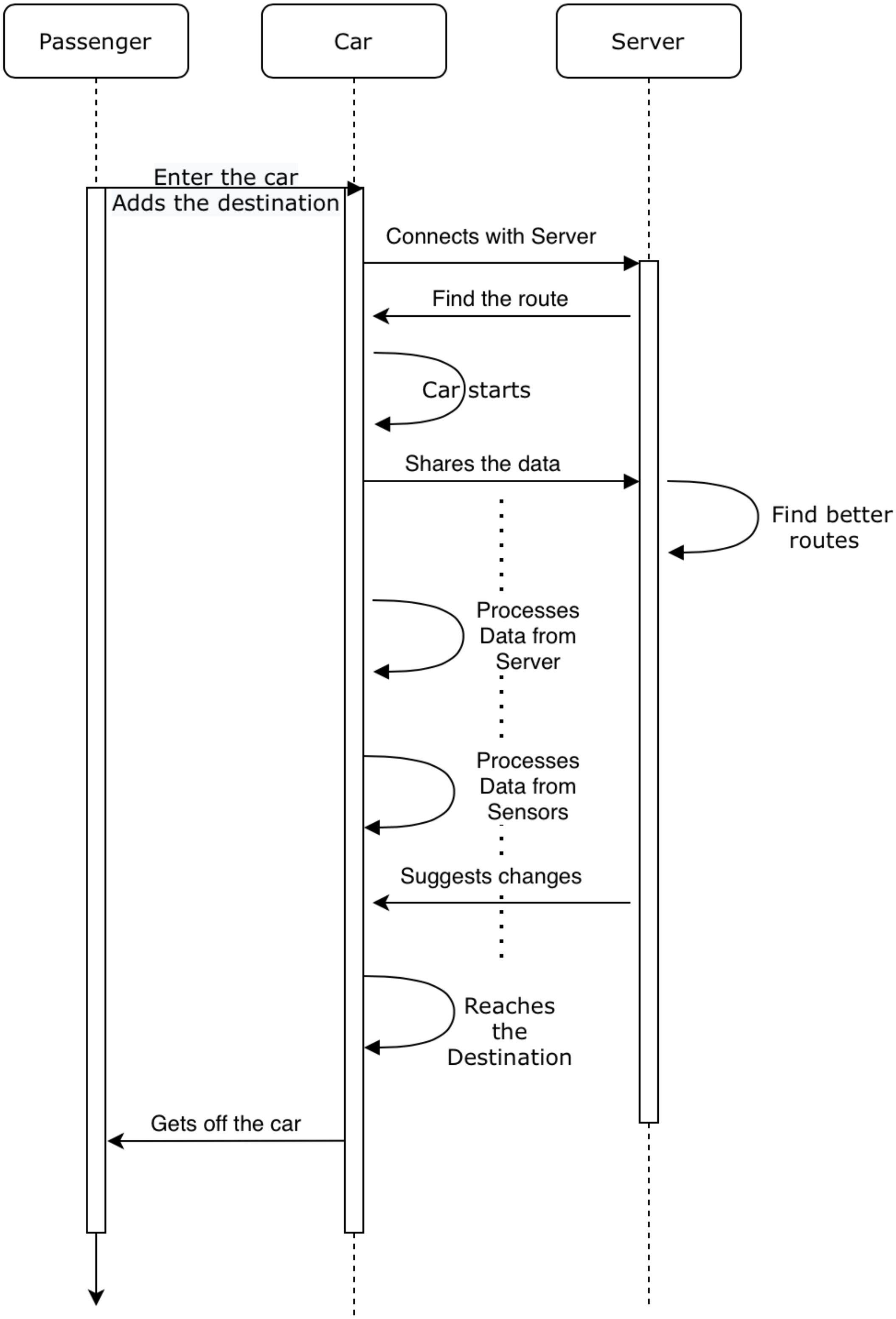
Following the same pattern as above the passenger gets into the car, after adding the location. The autonomous car system plans out the best route, looks for the traffic. From there it drives the car and notifies the passenger with the updates on route or mishappening. The sensors on the vehicle make sure to accelerate when the vehicle in front is slowing down and speed up when required. Along with that vehicle have the capability of sensing the vehicle around and making decisions to change lanes. The autonomous can also communicate with other autonomous vehicles on the same path and share the data for a better smooth ride.

Activity Diagram:



Activity Diagram represents the follow up of activities. It begins with the passenger's action of getting into the car and adding the destination, which is further acted upon by the car and server together. In case the car system is not able to connect to the server, the car can process the destination locally and find the route. With the route data, the car starts and performs more exchange of data with the server for better assistance. Finally, it reaches the destination.

Sequence Diagram

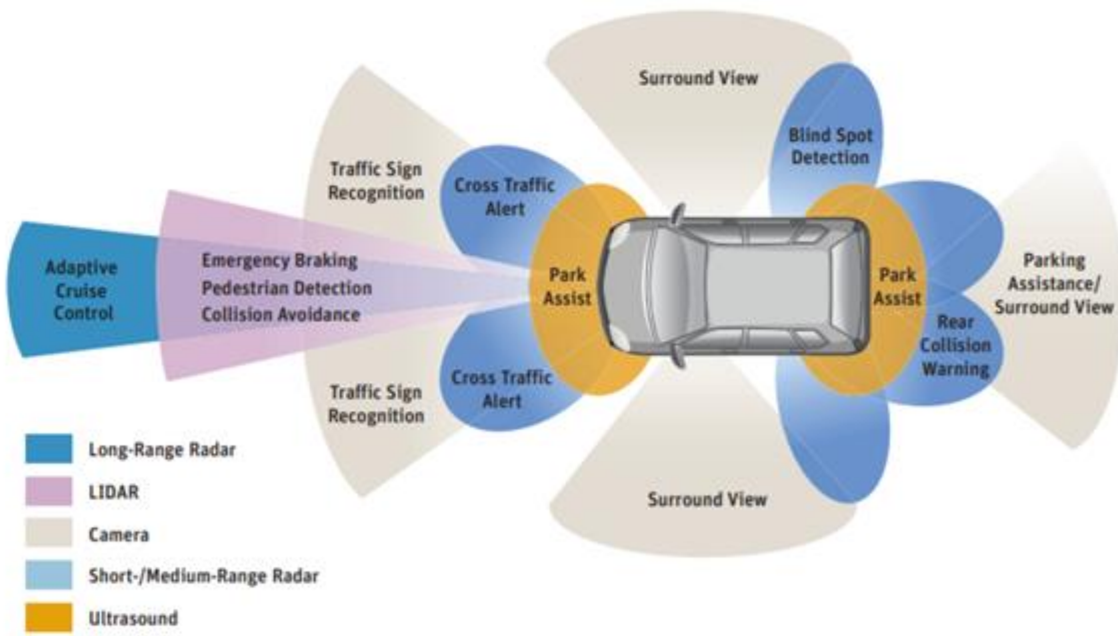


Passenger
Car
Server
Enter the car
Adds the destination
Connects with Server
Find the route
Car starts
Shares the data
Find better routes
Processes Data from Server
Processes Data from Sensors
Suggests changes
Reaches the Destination
Gets off the car

Sequence Diagram represents the sequence of the steps in the process. The actor (passenger) performs the first sequence by adding the destination and getting into the car. With that data the car connects to the server and exchanges the data. The car system looks for the best possible route. Then the car starts to drive and continuously shares the data with the server. Along with that car processes the data from the sensors to perform safe and smooth drive. Data from the server is used for optimization of route and critical data exchanges.

Finally, the car reaches the destination, and the passengers get off.

SYSTEM REQUIREMENTS:



1.Cameras:

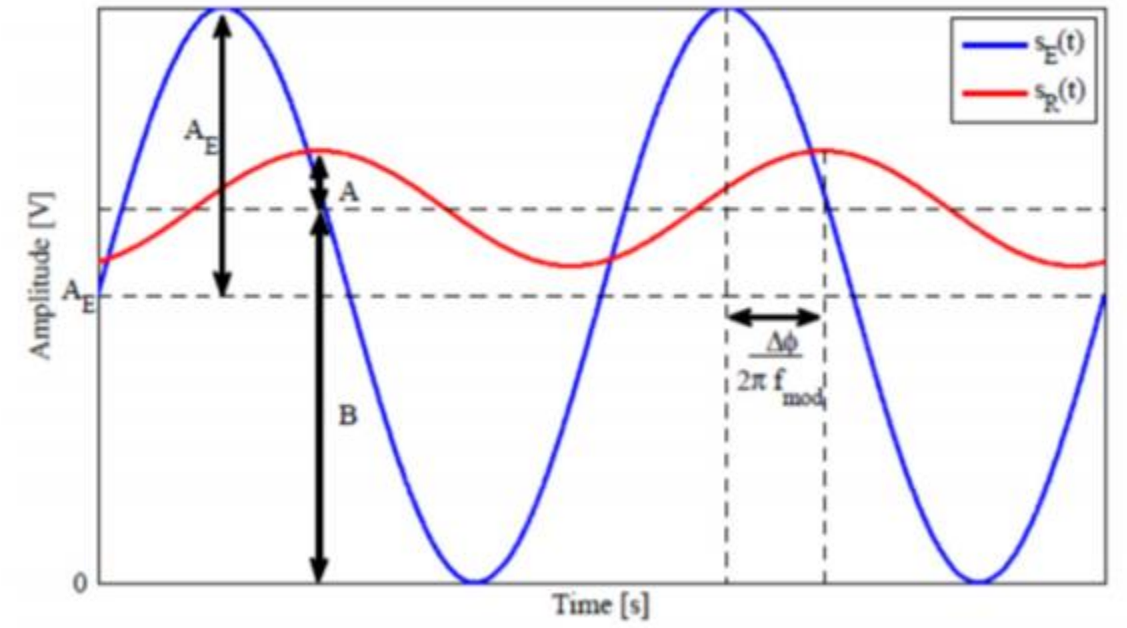
Monovision cameras are used in automated driving vehicle systems which capture the images and handle them to understand the basic signs on the road such as path markings, speed limit and many more signs that humans try to interpret. These cameras used will be helpful in comprehension of the road, traffic, and surroundings.

1.1 Perception System of Cameras:

In the perception system of autonomous vehicles and from some extent of view of the wavelength received by the device, cameras are often classified as visible (VIS) or infrared (IR). The element used by the camera to capture a scene is understood as an imaging sensor and has traditionally been implemented with two technologies. One is a Charge-coupled device (CCD) and the other is complementary metal oxide semiconductor (CMOS). CCD image sensors are manufactured by an upscale manufacturing process that confers unique properties like high quantification efficiency and low noise. CMOS was developed to scale back the value of producing at the expense of reducing its performance. The planning of the extraction architecture of the luminosity values allows the choice and processing of regions of interest (ROI); furthermore, the CMOS device features a lower consumption than CCDs. These characteristics make them the foremost used technology for mobile devices. On the other hand, CCD technology features a high dynamic range and better image quality in low light environments. The differences of both technologies begin to overlap, and it is expected that within the future, CMOS technology will replace CCD.

1.2 Image Capturing by the autonomous vehicle system:

VIS cameras capture wavelengths between 400 nm to 780 nm the minimum score. Equal as the human eye can. The seen spectrum is split into 3 bands or channels: R, G and B, to be able to be coded separately. These gadgets are the most typically used in AV notion systems to acquire information approximately the surroundings of the automobile because of their low cost, excessive satisfactory shade facts, and high resolution. The massive quantity of information generated by the device supposes a similar hassle for the processing system. The most commonplace packages are BSD, aspect view manipulate, twist of fate recording, object identity, LCA, and signs detection. VIS cameras are distinctly affected by versions in lighting fixtures situations, rain, snow or fog situations and for this reason are mixed with RADAR and LiDAR technology to boost its robustness. The mixtures of two VIS cameras with a regarded focal distance lets in stereoscopy imaginative and prescient to be accomplished, which adds a new channel called depth information. Cameras with those capabilities are called RGBD. These gadgets supply a 3-D representation of the scene around the automobile. IR cameras are passive sensors that paintings in infrared (IR) wavelength stages between 780 nm to 1 mm. There are many devices which work on this spectrum due to the fact fewer mild interferences exist (LiDAR). Perception systems that consist of IR cameras paintings in close-to-infrared (NIR: 780 nm–3 mm) or mid-infrared (MIR: 3mm–50mm, called thermal cameras) stages. The makes use of NIR generally to update or complement VIS cameras. IR cameras are used: (1) In situations wherein there are peaks of illumination; for example, at the exit of a tunnel, while riding in the front of the solar or when lengthy mild crosses the auto; and (2) in warm body detection, consisting of pedestrians, animals] or other vehicles. In these instances, the thermal cameras allow the segmentation manner to be simplified to fewer operations based on thresholds and they are now not affected by climate or lighting fixtures situations. On the opposite hand, they deliver a grayscale picture and the bigger cellular length of the image sensor considerably reduces its decision. ToF cameras are energetic sensors that use the time of flight principle to obtain a 3-d illustration of the gadgets within the scene. ToF cameras help in emitting NIR light pulses of 850 nm with an LED (Light Emitting Diodes) array and they degree the distinction in section $\Delta\varphi$ among the modulated signal emitted (sE) and the sign obtained (sR) to compute the distance.



$$\bar{d} = \frac{c}{2} \times \frac{\Delta\varphi}{2\pi f_{mod}}$$

The distance degrees from 10 meters for indoor scenes and approximately four meters for outdoor scenes, depending on the wide variety of LEDs within the matrix. As with IR cameras, they have got a low resolution due to traits of the wavelength they are required to seize.

2.Radar:

Automated driving vehicle systems rely on the radar systems. These radar systems which are employed are of two types. One typically operable for short range and other which can be used to identify the objects by using long range operable radar. The two types of radar have their limitations. The short-range radar system helps the vehicle understand the immediate surroundings around the vehicle and on other hand long range radar system helps in identifying the objects in distant from the vehicle and evaluate the speed and type of object.

2.1 Radar Sensing:

A radar electronic device operates via transmitting a specific kind of electromagnetic wave to stumble on gadgets or substances in the surroundings from the character of the echo sign that the radar device receives. The radar is used to extend the functionality of man's senses for observing his surroundings, particularly the feel of imaginative and prescient. The fee of radar lies no longer in being an alternative to the eye, but in doing what the attention cannot do. Radar cannot remedy detail in addition to the attention, nor is it yet capable of spotting the shade of objects to the diploma of class of which the attention is capable. However, radar may be designed to look via the ones situations impervious to regular human imaginative and prescient, consisting of darkness, haze, fog, rain, and snow. In addition, radar has the advantage of being able to degree the space or variety to the item.

3.Localization and Mapping:

The Global Positioning System keeps the track of the vehicle on the map. This comes into play from the beginning of the journey to plan the route to serve any need of modifying the route or notifying the service provider in case of emergency. The GPS data along with data from cameras and radar precisely determines the location of the vehicle at any point during the drive.

3.1. Position and Telemetry:

A variety of systems and techniques exist to determine the placement of an automobile. The number one department amongst role monitoring structures is whether the gadget takes measurements based totally on an external international scope or inner local scope. Systems that make use of an external scope such as GPS will determine the position as an absolute cost where the vehicle exists on a present map. Localized gadgets such as Wheel encoders will measure unique elements that are associated with the motion of the vehicle across the riding aircraft and decide the location of the automobile primarily based on previous positions of the car.

3.2. GPS:

GPS uses a sequence of satellites in orbit around earth to allow a receiver to triangulate and determine its precise role on this planet. When the placement is polled at exclusive points in time the direction of the car may be determined, and the velocity and accelerations can be calculated. For a worldwide positing machine to characteristic successfully, it is far-flung required that the environment that the car is in to have already been mapped and beacons or markers to were already positioned. Accuracy is the number one evaluation factor for a global sensor. The accuracy describes how close the device can appropriately determine the position of the receiver. Accuracy within 1 meter describes that the tool can be inside a meter of the suggested values. Typical accuracy values are inside 15 meters.

3.2.1 A* Algorithm Use

A* search algorithm scans for the best possible path, investing in the cheapest / most cost efficient node on the graph alone the way. It prioritizes these routes and follows paths that seem to have the shortest outcomes. If at any point down the line it senses an obstacle down a chosen path, it will avoid it. It’s flexible and can be used in most cases, but is expensive on the car’s memory. It’s versatile enough, however, to warrant its use.

3.3. Local Sensors:

Localized sensors degree aspects which might be nearby to the car itself. Wheel encoders, accelerometers and gyroscopes are examples of sensors that depend most effectively on the car to acquire facts. Accelerometers will measure the inertial forces acted upon the car at some stage in tour and could reply lower back with a signal this is proportionate to the amount of force that changed into measured. Using the direct accelerations skilled by way of the automobile one can, over the years, decide the route traversed by the automobile by means of calculating role from the acceleration facts. Combining more than one kind inner sensors collectively will produce an inertial navigation machine (INS). In localized sensors the principle comparison points are decisions that describe what variety and importance of can be reasonably accurately measured, polling price is the frequency at which the device measures the forces performing upon it and flow over time, that is the quantity of inaccuracy so as to construct through the years. The powerful range and magnitude of the sensor offers a concept of what packages the sensors have been designed for and what styles of accelerations the tool can reasonably handle.

3.3.1 Accelerometer:

An accelerometer with a 2g range may be beneficial in determining the orientation of a handheld device, however, could be a terrible desire to be used inside the black field of a plane. Drift is due to small inaccuracies within the dimension building up over the years. As the inaccuracy builds, any suggested values turn into skewed and unreliable. The difficulty of going with the flow is a nuisance for pinnacle-notch components however can be flat-out crippling for ordinary sixteen business sensors as the flow in these inexpensive components can fast construct in just a number of seconds.

3.4. Simultaneous Localization and Mapping:

Simultaneous localization and mapping algorithm which is one of the most basic implementations, which simply translates the local landmarks and robot pose and translates them to a global coordinate system. However, localization and mapping algorithms have been both into elements that can be treated as particles, as well as multiple phases in the processing of each particle. The structure of these phases is primarily designed to facilitate future development of the system by allowing developers to swap out single sections of the localization and mapping algorithm and thereby speed up the development process.

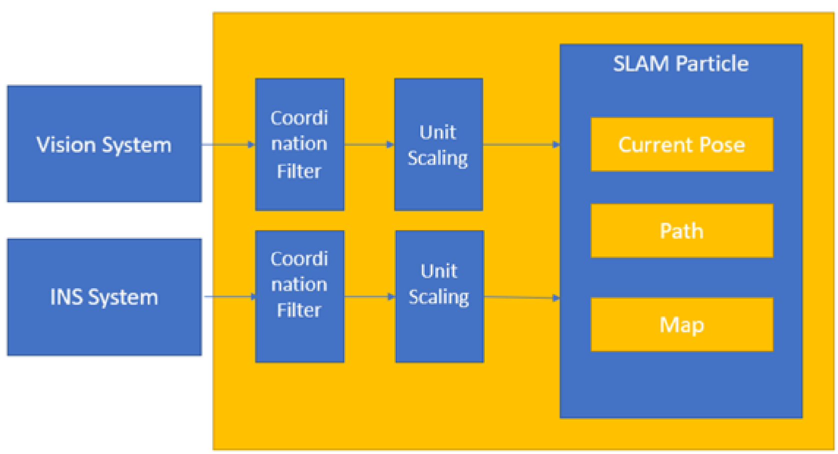
3.4.1 Landmark Detection and Mapping:

The basic localization and mapping implementation might region all the measured landmarks on a global coordinate plane and replace the robot position based totally completely on the facts collected from the inertial navigation system. In this situation, there is no blunders correction on the way to bring about dimension errors that accumulate through the years. For noisy sensor systems, the mistake might probably be huge enough to render the localization and mapping algorithm very erroneous for facts logging runs of nontrivial period. However, this simple implementation is beneficial for demonstrating the simple transforms necessary to carry out fundamental localization and mapping calculations.

The primary transforms that incorporate the localization and mapping algorithm clearly take facts from the neighborhood coordinate plane attached to the robot and translate them right into a worldwide coordinate aircraft that must be steady between samples. Using the basic inputs to localization and mapping set of rules, that are the change in automatic vehicle role, and the places of all the landmarks local to the vehicle, a fundamental implementation has fundamental steps:

3.5. Localizer Sub System:

The Localizer subsystem is liable for estimating the self-driving car pose (position and orientation) relative to a map or road (e.g., represented by curbs or road marks). Most general-purpose localization subsystems are supported by GPS. However, by and enormous, they are not applicable to urban self-driving cars, because the GPS signal cannot be guaranteed in occluded areas, like under trees, in urban canyons (roads surrounded by large buildings) or in tunnels. Various localization methods that do not depend upon GPS are proposed within the literature. they will be mainly categorized into three classes: LIDAR-based, LIDAR plus camera based, and camera-based. LIDAR-based localization methods rely solely on LIDAR sensors, which supply measurement accuracy and ease of processing. However, despite the LIDAR industry efforts to scale back production costs, they still have a high price if compared with cameras. In typical LIDAR plus camera-based localization methods, LIDAR data is employed only to create the map, and camera data is used to estimate the self-driving car's position relative to the map, which reduces costs. Camera-based localization approaches are cheap and convenient, albeit typically less precise and/or reliable.



Block Diagram of the localization and mapping system

The generic phases of the localization and mapping algorithm, in execution order, are listed below:

3.5.1. Preprocessing:

This phase is a catch-all for any adjustments to the data before the main localization and mapping algorithm starts, such as reordering of the landmarks, or culling landmarks that are too close together.

3.5.2. Predict:

This phase primarily uses the control to determine the new vehicle state.

3.5.3. Data Association:

This phase determines which new landmarks correspond to known landmarks. To perform this computation, this phase relies on the predicted robot pose.

3.5.4. Update Pose:

Performs an update on the robot pose using the known landmarks to correct the original prediction.

3.5.5. Update Landmarks:

Uses the newly updated pose to update all the landmarks that have been spotted in the landmark measurement.

3.5.6. Post Processing:

A variety of techniques could be included in this phase, such as culling landmarks that have not appeared when they should appear.

3.6. Camera Based Localization:

A recursive Bayesian filtering algorithm is used to perform inferences within the graph by exploiting its structure and thus the model of how the car moves, as measured by the visual odometry. This algorithm is ready to pinpoint the car’s position within the graph by increasing the probability that this pose lies during a point of the graph that's correlated with latest car movements (distance traveling straight and up so far curves) and by decreasing the probability that it's during a point that's not correlated. Two complementary vision-based localization techniques were developed, named Point Feature based Localization (PFL) and Lane Feature based Localization (LFL). In PFL, this camera image is compared with images of a sequence of camera images that's acquired previously during mapping using DIRD descriptors extracted from them. a worldwide location estimate is recovered from the worldwide position of the photographs captured during mapping. In LFL, the map, computed semi-automatically, provides a worldwide geometric representation of road marking features (horizontal road signalization). This camera image is matched against the map by detecting and associating road marking features extracted from a bird’s-eye view of the camera image with horizontal road signalization stored within the map. Location estimates obtained by PFL and LFL are, then, combined by a Kalman filter.

Off-the-shelf text extraction techniques are used to identify text labels in the environment. A MCL algorithm is employed to integrate multiple observations. The feature detection is performed mainly by a stereo camera. Localization is performed by a MCL algorithm coupled with a Kalman filter for robustness and sensor fusion. Some methods employ neural networks to localize self-driving cars to localize self-driving cars. They consist of correlating camera images and associated global positions. In the mapping phase, the neural network builds a representation of the environment. For that, it learns a sequence of images and global positions where images were captured, which are stored in a neural map. In the localization phase, the neural network uses previously acquired knowledge, provided by the neural map, to estimate global positions from currently observed images. These methods present error of about some meters and have difficulty in localizing self-driving cars on large areas

4. Lidar:

Lidar technology helps the automated vehicle to understand its surroundings in a better way. The Lidar technology system uses laser detection and ranging to create the three-dimensional profile of the objects. This technology helps the vehicle to understand the surrounding objects and make the travelling better by making it smooth.

LiDAR, an acronym for Light Detection and Ranging, with the aid of name it defines the practical precept of such a sensor. Automotive LiDAR sensors are being advanced as peripheral tracking sensors for the prevention of traffic accidents.

4.1. Principle:

LIDAR sensing is essentially a faraway sensing generation which emits laser mild beam with described depth and recognition, measures the contemplated beam arrival time detected by using the photodiodes (PD) in the sensor.

4.2. Obstacle Detection:

The accuracy of time of flight (TOF) measurements depends on the pulse width of the laser and the velocity and accuracy of the ADC used. The range equation gives the variety of semiconductor pulsed laser based on its energy in Watts and other machine and atmospheric situations and for dual flight distance to the position of the obstacle is:

For low-mild detection inside the receiver, APDs are extensively used, supplying a combination of high speed and high sensitivity unrivaled by using other detectors. The APD converts the obtained mild sign into an electrical current sign in share to the incident mild. Transimpedance amplifier converts the contemporary sign into voltage signal. The output of the transimpedance amplifier is generally transformed to a differential signal and amplified earlier than digitization via an ADC. At the stop, the gadget ought to be compatible for full 360 tiers views to locate its three-D environment. In addition, the processed statistics need to be provided to the user in actual time, so the far vital to have no less than delay among the information gathering and rendering the imaging.

4.3. Lidar Mobile Sensing application:

The HDL-64E (Mobile Sensing Lidar Application) features 64 emitter-detector pairs, each aligned to provide an equally spaced 26.5-degree elevation field of view, spanning from +2 degrees to -24.5 degrees. The entire optical assembly rotates on a base to provide a 360-degree azimuth field of view. The unit has a range of 120 meters and typically has a distance error of less than one inch. The unit rotates by default at 600 RPM (10 Hz) but can be instructed to run.

4.3.1. HDL-64E sensor direction Sensing:

The HDL-64E (Mobile Sensing Lidar Application) capabilities 64 emitter-detector pairs, all equally spaced 26.5 diploma elevation area of view, spanning from +2 levels to -24.5 stages. The entire optical meeting rotates on a base to provide a 360-degree azimuth discipline of view. The unit has a number one hundred twenty meters and generally has a distance error of less than one inch. The unit rotates via default at 600 RPM (10 Hz) but can be instructed to run among 300 and 900 RPM on the fly. The rotation price is computer controlled. The software registers a million distance factors in step with 2nd regardless of rotational velocity, offering horizontal angular decision of as little as .05 degree. The unit is each statically and dynamically balanced which minimizes any vibration felt with the aid of the user and additionally affords for a solid rendered photo. This overall performance, in phrases of point cloud density, body fee, and subject of view is advanced to every other sensor currently available.

4.3.1 Lasers in HDL-64E sensor:

The HDL-64E lasers each emit an optical pulse, five nanoseconds in length, as measured between the 50% points of the optical peak amplitude, with a most peak electricity output of 60 watts. Each laser is command charged just before triggering the laser the use of a fly again charging technique. The go back mild passes via a separate lens and a UV daylight filter out. The filter acts to lower the quantity of energy delivered through the solar, which can degrade the sign-to-noise ratio, thereby decreasing the overall sensitivity of the gadget.   The emitter-detector pairs are divided into two 32-laser banks. The upper bank (referred to as the upper “block”) is physically placed near the top of the unit and is directed at the better half of the elevation angles. The lower financial institution is positioned underneath the upper optical block and is intended for the decrease 1/2 of the elevation field of view and is therefore looking at shorter distances than the top block. Because the upper block is directed at better elevation, and thereby similarly distances, the angular distance traveled among optical pulses is bigger than the lower block. The other key trouble, cannot be not noted, is laser protection. The emitter of HDL-64E carries a laser that emits in 905nm wavelength (class-1 laser) and this near infrared radiation is safe for the naked human eyes.

4.4. Digital Record Display for Vehicle:

As the LiDAR sensor spins on top of the car the digital facts are a series of point clouds from the encompassing. The factors come from a single emitter-detector pair over flat ground seems a non-stop circle. The 3D creation of the picture recorded with HDL-64E and there are not any breaks within the round facts round the automobile in any of the purpose clouds. This gives you that the laser pulse repetition price and better block to lower block duty cycles (emitter and detector arrays) are configured well for the sensor. A repetition rate that is too slow would end in each of the circles might seem to be the dotted lines. The simplest areas of blanking, wherein there aren't any records, are between the factor clouds or during which a shadowing impact occurs, where a target is inside the optical transmit route, and as a result no statistics can be received from behind the goal. The blanking within the back of the rear mattress of the car is an example of this shadowing effect. The advanced excessive definition LiDAR scanner designed for independent vehicle navigation, mapping, surveying, commercial automation, and different makes use of. However, the S3 version of the HDL-64E offers advanced accuracy and a better information fee than the authentic version. Capture excessive definition three-D statistics about the encircling surroundings. With its complete 360 HFOV by means of 26.8 VFOV, the HDL-64E gives extensively more environmental information than previously to be had. With its 5 -20 Hz user-selectable body rate and over 2.2 million points according to 2nd output price, the HDL-64E S3 offers all the space sensing facts you will ever need. The unit’s improvement has been centered on excessive records fee, excessive robustness, accuracy and straightforward 100 MBPS Ethernet interfacing to the hand over user.

5. Ultrasonic Sensors:

These sensors help not only understand the surroundings but the vehicle itself and can be helpful in better understanding of the drive and enable very smooth ride to the riders. These ultrasonic sensors can be enabled in the various parts of the vehicle system such as acceleration system, pressure points to detect the abrupt change applied on the vehicle system and the light sensors

5.1 Road Object Sensing

5.1.1 Pothole detection

6. Wireless Data Network:

The wireless data network is the key communication idea in the automated vehicle system. The wireless data network includes various technologies such as Wi-Fi, Long-Term evolution networks, and many other evolving and advanced wireless technologies.

6.1 Dedicated Short Range Communication (DSRC):

DSRC is a quick-range (much less than 1,000 meters) wi-fi carrier specifically designed to be the wi-fi hyperlink among vehicles and between vehicle-to-automobile (V2V) and roadside infrastructure. DSRC is supposed to guide protection packages which include avoidance of intersection collisions. DSRC is also used for non-protection messages and automobile diagnostics.

6.1.1 Bluetooth:

Bluetooth is a wireless era that makes use of quick-wavelength radio transmissions to trade statistics from fixed and mobile gadgets over short distances. It creates a non-public network with a high degree of safety. It also allows mobile phones brought right into a car to direct incoming and outgoing calls via the car, developing a hands-loose wi-fi smartphone. While it is on the whole used in vehicles to extend the capabilities of wi-fi phones, it could additionally be used as a method of facilitating the vehicle’s conversation, either by way of allowing V2V communications or by transmitting information for re-transmission to a wireless telephone.

6.1.2 Wi-Fi:

Wi-Fi is a famous technology that allows an electronic tool to alternate statistics wirelessly (using radio spectrum) over a computer community, inclusive of excessive-velocity Internet connections. There are a few one-of-a-kind approaches automakers can attain Wi-Fi in-automobile. It is simply every other way to perform the same thing: a dependable internet connection while at the move for more than one user right away.

6.1.3 Wireless Router for Mobile hotspots:

This is a cell model of the home-primarily based wi-fi router. It connects thru a mobile network to the Internet

6.1.4 Wi-Fi Enabled in-car telematics systems:

These systems enable the user to pair their smartphone and then use it as a Wi-Fi hotspot for their smartphone connection to the Internet.

6.1.5 Short-range Optical Network:

Optical wireless communication (OWC) structures should provide extended throughput and reduced complexity aera properly-suitable for short-range wi-fi communications. More specifically, OWC hardware may be taken advantage of when a self-using vehicle is within range of metropolis infrastructure outfitted with the right mechanisms. These answers can be deployed inside the transportation infrastructure (site visitors lighting, light posts, car charging stations) to speak with automobiles. Depending on the infrastructure implementation, those OWC solutions may also encompass a hard and fast factor-to-factor OWC configuration (for charging station infrastructure) or a fixed point to transferring point OWC configuration (for traffic mild or mild posts infrastructures).

6.1.6 Connected Vehicle system with Network:

5G networks in that they make better use of the radio spectrum, boosts mobile network coverage, security, and safety, while delivering environmental benefits for citizens and consumers. They use short-range direct communications at 5.9 GHz, high levels of mobile network coverage along the roads, and sufficient service-agnostic mobile network spectrum for mobile network-based communications.

6.1.7 Wireless Battery Management System:

Wireless battery management system (WBMS) enables automotive manufacturers increased flexibility to scale electric vehicle fleets into volume production across a wide range of automated vehicle classes. The data can be monitored remotely throughout the battery lifecycle – from assembly to warehouse and transport through installation, maintenance.

6.1.8 In vehicle Satellite Internet Connectivity:

The vehicle gets assistance from the navigation satellites to know the path and also to find out the trajectory.

7 Vehicle to Vehicle Communication(V2V):

The transportation has observed most of the developments in the recent years and all the credit goes to the applications of the intelligent systems. With the help of new technologies, the vehicle communicates with each other in a convenient manner and which avoids the problems such as traffic congestion and accidents. All these systems should be able to connect and communicate with each other. The Vehicle to Vehicle communication consists of the wireless data transmission among the vehicles. The primary purpose of the communication between the vehicles is to reduce the number of accidents. The vehicles in this network or mesh update their speed and location. The centralized communication system allows the transfer of information of the vehicles to every other vehicle. The topology used helps in creating the most robust network. The failure of one node in the system or the malfunctioning can be minimized, and all the other vehicles or nodes connected in the system can be made to reach the destination without any mishap. The Wireless Personal Area Network is used rather than conventional wired networks which offer very convenient and cost-effective solutions.

The communication or the interaction between the vehicles and various other entities requires the information exchange between them by using the proper protocols of communication. Some of the protocols designed to support the communication are the following. IEEE802.11p and LTE-V2V standards are designed to support the vehicle transmissions.

7.1 IEEE802.11p:

This protocol enables the devices to receive the information at a speed of Mbps to 27 Mbps for short range communication in a radius of 300m. This protocol also helps the vehicle to communicate in two ways V2V (Vehicle to Vehicle) and (V2I) Vehicle to Infrastructure.

7.2 Cellular Technologies:

The cellular technologies such as third generation Partnership Project(3GPP), Universal Mobile Telecommunication System (UMTS), fourth generation communication system Long Term Evolution (LTE) and their progression has increased the capacity and speed by utilizing various radio interfaces with many core network improvements. The features such as LTE provide the downlink peak rates up to 300 Mbps, uplink peak ones of 75 Mbps, transfer latency of less than 5ms and transmission range up to 100 km in the radio network.

7.3 Cellular Protocols:

The other protocols also involve Bluetooth and IEEE802.1.4/ZigBee. The primary goal of these protocols is to minimize the connection times and maximize the transmission range in adverse conditions such as high mobility and vehicular density. The primary aim is to use these technologies and improve the road safety and avert any kind of dangerous situation. The vehicle to Vehicle(V2V) infrastructure provides communication models which are used by various vehicles applications. The infrastructure helps in creation of a mesh network whose nodes are not just the vehicular system but also the mobile devices and wireless modules.

7.4 Network Protocols:

The network or the topologies can be of two types, one in which each and every node are connected with each other and with the help of this kind of network the nodes or the vehicles instead of depending on the centralized base station can coordinate the flow of messages and prevent any accidents. The other topology in which nodes can randomly organize themselves and connect to the centralized control system and await massages from the central system to take any action further to prevent the accidents. The automated driving system helps in taking the decisions based on the information they receive from the network they are connected to. Depending on the type of event related to the risk of accident the vehicle itself can independently take preventive measures. The Vehicle to Vehicle communication will be more effective and increase the performance in the field of security by making the interaction possible between the vehicles. The communication is improved by the embedded system which relies on data from the various sensors such as on-board cameras, proximity sensors, and radar systems. From this we can understand the primary purpose of a vehicle or node being connected to a network is to improve the security and take more effective choice in solving the emerging problem on the road. These embedded systems with collaboration of the various sensors can be called as the Original Equipment Manufacturer (OEM). The centralized OEM system today helps in making the following decision such as:

7.4.1 Blind Spot Monitoring (BSM):

This assistance system monitors the rear-view mirror's blind spot using the radar systems. This system helps to inform the driver the details of the vehicle arrival with visual signals integrated in the left and right rear-view mirrors depending on the side where the vehicle in the front passes.

7.4.2 Electronic Stability Program (ESP):

The system helps the vehicle understand the terrain and avoids the vehicle to oversteer or understeer and helps in maintaining the trajectory along the path.

7.4.3 Forward Collision Warning (FCW):

The radar systems help in enabling the system. The system helps in recognizing the objects and obstacles on the path and if the speed of the vehicle is at a risk of colliding with the object the driver inside the vehicle can be alerted by acoustic sensors and provide the warning on the display on the vehicle.

7.4.4 Automatic Emergency Braking (AEB):

If the driver of the vehicle brakes inadequately or does not apply the brakes in the manual mode of driving the emergency braking system with the assistance of electronic stability will help in reducing the impact of the collision. In this the features of the vehicle are alerted such as air in the airbags is pumped and the sunroof of the vehicle is closed along with the windows such that the accident does not impact the person inside of the vehicle in case of overturning of it.

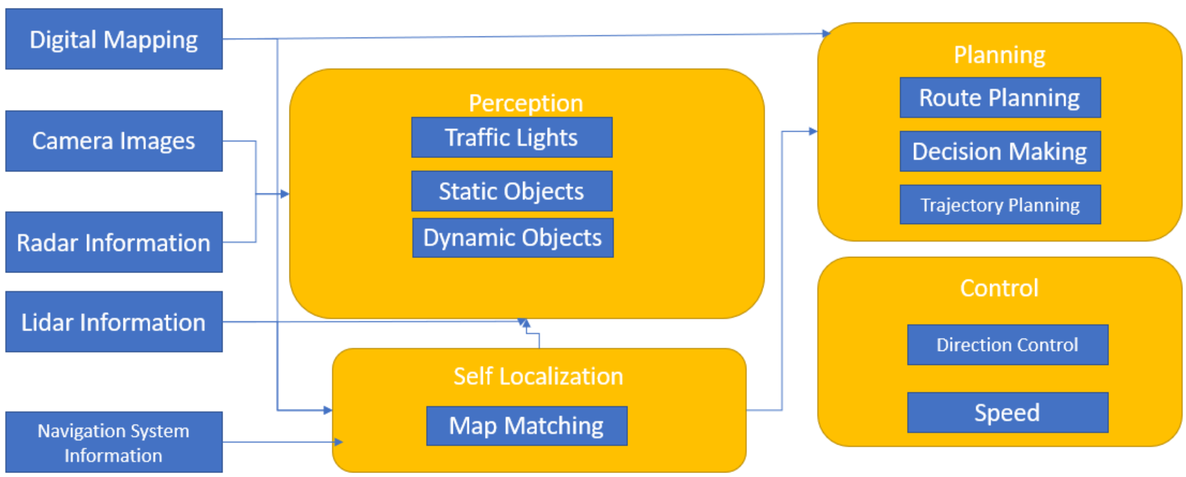
7.4.5 Brake Assist System (BAS):

This system mounted on the vehicle braking system helps into operation in the event of any sudden emergency braking such as when the brake pedal is pressed in a fast and aggressive way that the pressure sensors receive the information and help in activation of the anti-lock system in the vehicle. This system helps in assuring the better braking system automatically in the automated driving vehicle system. The BAS helps in the activation of the automated raising of the pedal until all the ABS (anti- lock) wheels of the vehicle function in a correct manner.

7.4.6 Lane Departure Warning System (LDWS): The system in the vehicle helps to warn the distracted driver exceeding the lines on the roads. It can be activated and can be used to warn the driver by acoustics signals if the vehicle crosses the line without the proper preparation such as the usage of the indicator.

8 Decision Making:

There is a wide variety of information to be processed by the onboard computer to drive autonomously, but three major technological developments are required. The first technology is self-localization. In automated driving systems that travel on various roads including urban roads, there are many systems that operate using HD maps. A digital map has high accuracy and various kinds of recorded information, which makes it possible to reduce the technical level required for automated driving. On the other hand, to effectively use the HD map, it is necessary to always estimate the vehicle position on the map with high accuracy using onboard sensors. In general, decimeter-level accuracy is required. The second technology is environment recognition. Since the automated vehicle recognizes its surrounding environment using onboard sensors and makes situational decisions based on the recognition results, it is important to understand the environment around the vehicle and to predict how the conditions can change. In addition, for the vehicle to behave smoothly in various types of traffic situations, it is necessary to recognize road features such as traffic lights. The third technology is trajectory planning. It is necessary to plan the behavior of the vehicle in real time by integrating recognition results in terms of self-localization, surrounding perceptions, and digital map information. These three technologies were first developed in the field of mobile robots. Because various situations can occur in a traffic environment where human drivers and automated systems are mixed, specialized technologies must be developed for the driving situations encountered by an automated vehicle.



Block Diagram of Process Flow in Automated Driving

8.1 Self-Localization Technology:

The first technology is self-localization. In automated driving systems that travel on various roads including urban roads, there are many systems that operate using HD maps. A digital map has high accuracy and various sorts of recorded information, which makes it possible to scale back the technical level required for automated driving. On the opposite hand, to effectively use the HD map, it is necessary to always estimate the vehicle position on the map with high accuracy using onboard sensors. generally, decimeter-level accuracy is required. The second technology is environment recognition. Since the automated vehicle recognizes its surrounding environment using onboard sensors and makes situational decisions supporting the popularity results, it's important to know the environment around the vehicle. to get decimeter-level accuracy, a LiDAR-based method was studied due to the high measurement accuracy of the sensor and a robustness to changes in day and night. These methods generally estimate the situation of the vehicle by matching road paint and building shape information along its path road as landmarks. Additionally, for low-cost implementation, some camera-based methods were proposed that match image observations onto a 3D LiDAR map. On the opposite hand, self-localization methods that utilize non-LiDAR maps also are being considered. These methods estimate the position by using image features or MWR features as a reference map. However, currently, the accuracy of the obtained position is inferior to the LiDAR-based method. it's necessary to pick an appropriate method consistent with the driving conditions, sensor specifications, and required accuracy.

8.2 Surrounding perception technology:

In surrounding visual perception, road features like traffic lights; surrounding obstacles; and traffic participants like vehicles, pedestrians, and cyclists must be recognized in real time using onboard sensors. so as for the automated vehicle to drive on public roads, it's a crucial task to acknowledge road features along the traveling lanes to follow traffic rules. Recognition of static road features like speed limits and stop lines are often omitted by registering them on the digital map as prior information. However, dynamic road features like traffic lights got to be recognized in real time. Therefore, the traffic signal is one among the foremost important dynamic road features in intersection driving. The traffic lights are often recognized only employing a color camera because it's necessary to classify the lighting color. For smooth driving at intersections, it's necessary to acknowledge the traffic signal states from a distance greater than 100 m. In related works, a previous map-based detection method was proposed. Introducing a digital map makes it possible to work out search regions to scale back the amount of false detections. Recognition methods using circular features, which are the essential shape of traffic lights, and recognition methods using DNN are reported. The popularity of static obstacles round the vehicle requires accurate measuring accuracy. Generally, surrounding obstacles are detected using range sensors like LiDAR, stereo camera, and MWR. to scale back the influence of instantaneous false detection, an occupancy grid map is generated as a 2D or 3D static obstacle map with free space by applying binary bayes filter as time-series processing. Additionally, to acknowledge surrounding traffic participants, a classification by machine learning is performed using the thing shape obtained from the range sensor and therefore the image information as input features. In recognition employing a range sensor, the observation points obtained by the sensor are clustered, and therefore the object category is assessed using machine learning like Adaboost and Support Vector Machine (SVM) from the features of every shape of those objects. If the space to the thing is about several tens of meters, a dense observation point cloud is often obtained, then the detailed shape of the thing is often confirmed. However, there is a drag that it is difficult to get detailed shape information for distant objects because the obtained point cloud is sparse. On the opposite hand, in recognition using camera images, dense observation information is often obtained compared to LiDAR, then it's possible to acknowledge distant objects over 100 m by selecting an appropriate lens. In recent years, since graphic processing unit (GPU)-based acceleration became possible, deep neural network (DNN)-based recognition was developed as a camera-based recognition method with high accuracy. However, it's difficult to get the space information of the thing directly because these methods can obtain the popularity result as an oblong bounding box up the image. Therefore, to get the relative position of the recognized objects, it's necessary to accumulate distance information by sensor fusion employing a stereo camera or other range sensor. Additionally, to traffic participant recognition, it's necessary to predict the state of objects after several seconds so as to perform safe collision detection and harmonized driving like distance-keeping driving. Therefore, it's important to estimate not only the positions of the dynamic objects but also the speed and acceleration. Generally, state estimation of surrounding objects is performed using probabilistic algorithms like a Kalman filter or particle filter. Since the space to the thing must be measured, range sensors like LiDAR, MWR, and stereo cameras are mainly used. Moreover, a way employing a mono-camera has also been proposed. Robust object tracking is often implemented not only by employing a single sensor but also by fusing multiple sorts of sensors. To predict the longer-term trajectory of a recognized object, it's effective to use the road shape information from the digital map. Additionally, to the present motion state of the recognized object, the behavior after several seconds are often predicted by using the road shape and its connection information. Moreover, the prediction of more appropriate behavior is often expected by introducing traffic rules and therefore the interactions between surrounding traffic participants.

8.3 Trajectory planning technology:

The autonomous vehicle system shall include the technology where it can make decisions and plan the trajectory.

8.4 Route Planning:

Decision-making during automated driving requires three sorts of situational judgment. The primary technology is route planning. this is often familiar in car navigation systems, etc., but it's necessary to look for the route within the lane level from the present position to the destination. In an environment where road information from a digital map exists, it's possible to look at the route using dynamic programming along the connections of roads. If there's no explicit road information like a parking zone or an outsized space, it's necessary to look for the optimal route from the drivable area.

8.5 Travel Plan

The system shall create an itinerary that complies with traffic rules. it's essential to follow the traffic rules when traveling along the route. especially , when making an entrance judgment at an intersection, it's necessary to secure a secure procedure in consideration of the popularity results of the traffic signal status and therefore the stop line position, and therefore the positional relationship of the oncoming vehicle and pedestrians on the pedestrian crossing . Additionally, it's important to think about the priority relationship between the present road and therefore the destination road when driving through an intersection. Therefore, it is a crucial task to gauge things while logically processing the travel in such traffic conditions.

8.6 Trajectory Optimization:

The system shall optimize the trajectory in real time. For the obtained route, trajectory planning is performed to look for the minimum cost, collision-free trajectory the. For the obtained route, trajectory planning is performed to look for the minimum cost, collision-free trajectory. Flexible automated driving is often realized by designing the driving behavior on a public road as a decision-making model. These trajectory generation methods can theoretically guarantee the continuity and smoothness of the determined trajectory by using polynomial functions. On the opposite hand, in recent years, machine-learning-based approaches for generating control commands or trajectories were researched and presented using CNN (Convolutional Neural Networks). The input information contains multidimensional data like the camera image or the positions of surrounding objects. Then, the neural network can produce a driving output behavior like smooth acceleration. Since the DNN can obtain adaptive behavior by machine learning, it is often expected to be applied to a good range of environments. On the opposite hand, since the obtained behaviors like lane keeping driving are still relatively simple and primitive, it's necessary to style a learning model that has a rule-based approach.

9 Cyber Security in Autonomous Vehicle System:

A connected automated vehicle is subjected to cyber-attacks through its various network interfaces to the overall public network infrastructure as well as its direct exposure to the open physical environment. An attack surface of a system is that the sum of the varied attack vectors, that is the various points where attackers can make attempts to inject data to or extract data from the system so on compromise the protection control of the automated vehicle. Automated vehicle systems can be subjected to the quality attack surfaces of an automatic vehicle, such as the ones identified by the authors in, and potential attack sources through which automated vehicle security are often threatened. It is often observed that the attack sources are typically external agents or even an interior component with malicious intent that attempts to compromise the expected autonomy functionality of the automated vehicle. The Bluetooth interface of the automated vehicle is often considered a possible attack surface which can be compromised through plugging malicious devices (attack source) into this channel.

9.1 Cyber-Physical System:

An independent vehicle may be taken into consideration a particular type of Cyber-Physical System and a kind of Internet-of-Things machine. Cyber-Physical-Systems are complicated, heterogeneous allotted structures, typically which encompass a huge extensive style of sensors and actuators related to a pool of computing nodes. With the fusion of sensors, computing nodes, and actuators, that are connected through diverse method of communications, Cyber-Physical System cause to perceive and recognize adjustments inside the bodily environment, examine the effects of such adjustments to the operation of the Cyber-Physical System, and make realistic choices to answer to the modifications by using the use of issuing commands to manipulate bodily devices within the system; thereby influencing the physical surroundings in an self-maintaining way. Cyber-Physical-Systems act both with complete autonomy or at least present assistance for a human-in-the-loop mechanism as a part of a few semiautonomous manage capabilities. This dispensed closed-loop procedure permits CPS to remotely have an impact on, manage, automate, and manipulate many industrial operations.

9.1.1 Operational Technology Systems:

The massive adoption of Internet-enabled devices in CPS systems has thereby blurred the boundary between CPS and Internet-of-Things also known as Operational Technology Systems.

9.1.2 Automated Vehicle System security issues:

The automobile is attached to the outside international with automobile-to-infrastructure and car-to-vehicle site visitors-reputation information from visitors control infrastructure or navigation-related data received from every other self-sufficient automobile on the road.

9.1.3 Control Area Network:

The Cyber-Physical System is supported by way of actuators and sensors, which include tyre pressure sensor, crankshaft position sensor, light sensor and obstacle sensors and intra-car communications for supporting such Cyber-Physical System controls appear often through stressed connections called the Control Area Network. The intra-automobile communique protocols typically observe the managed area community bus preferred.

9.1.4 Security System Design:

The protection design of autonomous vehicles calls for that intra-automobile networks be carefully included and that get entry to from outside of the car. It is clear from preceding well-known assault research of self-sufficient automobile protection that, without right protection designs, even communications through those intra-automobile wireline standards are probably prone to security breaches. In addition, connections to the internet enable the self-sustaining vehicle to transmit operational records to the auto manufacturer. As a crucial machine from the attitude of autonomy capabilities, it's crucial that the verbal exchange link between the self-sustaining automobile and its producer be authenticated and the payload be correctly protected according with the nature of the operational records being transmitted from the self-reliant car to the manufacturer.

9.2 Technical Design Decisions:

In real world situations, security requirements/objectives always start from people. In this connection, the consideration is not only in terms of the cost of security attacks but also the cost of implementing security controls as well as the opportunity cost of limiting business operations due to risk-averse designs. In the context of autonomous vehicles, the prime security objective is inevitably the resilience of safety features of the autonomy functions. The people/social/environment factors are typically some of the major sources of vulnerabilities, which vary from system to system.

The following are the key steps for the building of a security system

9.2.1 Hypothesis of security system in Autonomous Vehicle:

Identification and building the hypothesis of a security system.

9.2.2 Identifying the security objective and requirement:

Depending on the vehicle identifying the objective and requirement of designing the security system.

9.2.3 Assessment of value and sensitivity of the security system:

Based on the vehicle type we try to identify the sensitivity of the security system.

9.2.4 Defining the security policy as per the requirements:

The security policy design is based on various factors of the autonomous vehicle system.

9.2.5 Estimation of capabilities and flaws of the security system:

Drawing the hypothesis to estimate the capabilities and flaws that are going to emerge out of the security system.

9.2.6 Designing of features with respect to sensitivity of security system:

Depending upon the type of vehicle and sensitivity and features of the vehicle building the feature of the vehicle security system.

9.3 Traditional Standard Security Policies:

The traditional security policies of the system are designed based on the three generic qualities. Confidentiality, Integrity and Availability. These policies are built on the combination of the physical and logical control measure.

Designing of the threat Model for security system:

The model is built on modern CPS and IoT systems, this threat model is discussed together with the notion of attack surfaces. Attack surface provides an entry point for an attacker to gain control of or exfiltrate information from the target system.

9.3.1 Adversarial Model:

The attack surfaces of a system are identified, security designers will need to estimate the likelihood that attacks may happen in real and operational situations. The adversary, in this model, is capable of hearing, intercepting, initiating, and synthesizing any message. Adversarial models can also be used for analyzing privacy guarantees.

9.3.2 Attack objective:

The attacker attempts to breach one or more of the security objectives. Integrity breaches of an autonomous vehicle would mean that the attacker is potentially able to take over control of the vehicle. To control communications between the autonomous vehicle and any third-party system, the attacker can violate the confidentiality and integrity of the communication channel, hence can potentially manipulate the safety related control functions of the autonomous vehicle.

9.3.3 Communication capability:

To intercept messages transmitted over different communication channels of a Cyber-Physical System PS. This determines what kind of messages are available to them for analysis and their ability to inject maliciously fabricated messages to the system.

9.3.4 Computing capability:

After gaining access to the Cyber-Physical System through breaching the trusted network, the adversary needs to execute tasks to gain control or damage the Cyber-Physical System. These typically require cryptanalysis of cryptograms, decoding of application protocol messages and reverse-engineering security-critical parameters. The attackers will need to carry out these tasks online or offline in an efficient manner, often requiring considerable computing power.

9.4 Infrastructure and Security Mechanisms:

Besides, it is vital to aid protection administration of sincere IoT devices which include key, identity, and privilege management of those devices. In a startling distinction from wired networks, for wi-fi and cellular ad-hoc networks, it frequently admits new contributors, and therefore needs to frequently set up stable verbal exchange channels.

9.4.1 Infrastructure for trust management:

A prime use case scenario for IoT devices are ad-hoc sensor networks, which find applications in vehicle to vehicle and vehicle to internet communication protocols. For these nodes control mechanisms for admitting new nodes and detecting malicious nodes are important prerequisites for maintaining security policies intact.

9.4.2 Secure Routing Protocol:

Systems rely critically on static/dynamic routing protocols, which can be subjected to diverse forms of assaults. Typical countermeasures for routing protocol assaults rely upon, firstly, a reliance on base station that enables authentication and encryption; secondly, multipath routing and, thirdly, stable geographic routing protocols.

9.4.3 Heterogeneous Network Integration:

Networks are generally associated with a heterogeneous blend of wireless communique structures, every of which comes with its personal safety protocols. Their interoperability can also require conversion of statistics formats that are difficult to adopt without partial understanding of the message payload. Furthermore, the viable presence of, and regularly undetected, diverse information channels remains a regular danger that wishes to be addressed through steady and sincere community management.

9.4.4 Secured Resources:

The computing and garage blocks of a CPS can be taken into consideration secured. The resources under this class want to be confident by way of only accepting authenticated and signed boot procedure. Secure storages may be designed via preventing known assaults like, statistics remanence; and in addition, opting for encrypted and authenticated information garages.

9.4.5 Trust Identification:

To be included inside the trusted network, it must take part in a robust identity protocol or be licensed with the aid of a centralized certification authority. This works in similar standards as in wi-fi sensor networks, in which management turns into challenging for low-quit devices. For one of these resources, acceptance as true with anchoring can be accomplished by the use of Physically Unclonable Functions. Typical adversarial fashions towards those are hardware Trojan elements, added in the production/repairing process.

9.5 System Security Design for the Autonomous vehicles:

When designing security for complicated structures along with the self-reliant vehicles, it usually includes the subsequent key steps. Identify the security objectives and necessities of the gadget, Assess the fee and sensitivity of the system to be covered, Define security policy in accordance with the security requirements, Estimate the talents of the adversaries, Design control capabilities that commensurate with the sensitivity of the gadget and the risks it is exposed to. To commence the security-by using-layout procedure inside a sound framework, it is crucial to set up the operation version of the autonomous vehicles so that safety targets and requirements can be analyzed in a holistic and systematic manner.

9.6 Designing and Operational Model:

Communication: Autonomous vehicles periodically send operation logs to the manufacturer to allow life cycle management and maintenance. It has wireless or wired interfaces to support firmware/software update/upgrade at maintenance and service workshops. It also supports communication with some traffic management system infrastructure for traffic flow control as well as remote control in case of emergency.

9.6.1 Sensing:

Autonomous vehicle is equipped with a variety of sensors to sense the physical environment and detect collisions.

9.6.2 Decision:

Autonomous vehicles have several navigation-related control functions that allow Level-5 autonomy, i.e., it requires real-time updating of travel routes, enables intelligent route planning and automatic steering in accordance with road conditions. It also has several safety-related control functions that allow Level-5 autonomy, i.e., it enables automatic steering, speed regulation and braking in accordance with road conditions.

9.6.3 Requirements for Security System in autonomous driving vehicle system:

Based on the features the requirements and objectives of the automatic driving system are determined

9.6.3.1 Integrity:

Integrity of remote-control functions of the automatic driving system emergency operation from the traffic management system so that no attacker can take over control of the autonomous vehicle driving system by tampering the remote-control system. Integrity of the sensor systems so that navigation and safety related control features will not be interfered by attackers through tampering the sensor data. Integrity of the navigation-related control operations such as steering, braking and speed control are performed in accordance with the sensed road conditions or from preprogramming route path.

9.6.3.2 Confidentiality:

Confidentiality of communications between for autonomous vehicle driving systems and its manufacturer so that robustness of the life cycle management and maintenance of the AV. Confidentiality of cryptographic keying materials stored inside the for autonomous vehicle driving system are ensured so that attackers cannot bypass higher level security mechanisms by siphoning the cryptographic keys.

9.7 Security Management:

While the security-by-design principles attempt to minimize the security risks in a systematic manner, security management for autonomous vehicle driving systems is necessary for continuous assessment of the security challenges during the entire lifetime of an autonomous driving vehicle system. The standards outlined earlier only help in assigning a quantification under a common assumption of threats, risks, and vulnerability and also it is important to assess these factors and undertake a rigorous cybersecurity testing, possibly in an automated manner.

9.7.1 The prominent methods in understanding the security management of the vehicle system:

9.7.2 Attack Tree Analysis:

A popular approach is to base on the Attack Trees, Threat and Operability. From a purposeful/characteristic factor of view, the threat is analyzed using the attack timber. Further, with the mixture of potential threats, the worst-case situation is recognized, and the hazard is quantified.

9.7.3 Threat, Vulnerability and Risk Assessment:

For Cyber-Physical-Systems the security gadget is designed and managed with the aid of the evaluation of the danger, vulnerability, and hazard control of the security system.

9.7.4 Software Vulnerability Analysis:

It is a technique for assessing the vulnerability of a software code. The idea of software vulnerability stems from the reality that the development and actual surroundings of a software implementation can differ extensively, more so for self-sustaining vehicle devices like useful resource-confined environments and underneath the have an effect on a malicious attacker.

9.8 Security Testing Methods:

The techniques are described for numerous forms of security structures. Based on the various sensitivity and necessities.

9.8.1 Penetration Testing:

Penetration checking is commonly finished as part of a security audit, below the setting of a "black container" or a "white container" test problem. In a black container placing, the device details are unknown to the tester, while within the white box placing, an effective adversary is assumed, and the system internals are furnished to the attacker. The aim of the penetration trying out to identify the vulnerabilities and investigate the system safety.

9.8.2 Red Teaming Testing:

This is a system for detecting network and system vulnerabilities by means of assuming the function of an attacker, additionally rather termed as ethical hacking.

9.8.3 Fuzz Testing:

In fuzz testing, a huge amount of random statistics is input to the software program system to make it crash. The aim is to check coding blunders and safety loopholes.

9.8.4 Network Testing:

In this test, the community resilience is tested by passing a wide variety of packets in short bursts. Further to the strain take a look at, the network configuration and the malicious activities, if any, are tested through acting packet decoding and matching community topology.

10 User Interface:

Users or passengers can interact with the vehicle using a verified mobile phone, the car in built screen and voice controlled virtual assistant. The user enters the information like destination, stops or preferred route. Along with that user interface is capable of handling any request such as change of destination, in mid of a journey.

10.1 Phone Application Capability

10.2 Information Presentation

10.3 User Authentication

10.3.1 Biometrics

11 Machine Learning Algorithms in Autonomous Vehicles:

Artificially intelligent systems take the inputs as the raw data and gain the knowledge from it by evaluating and extraction of the data from the data by applying various concepts of algorithms and concepts.

The ability of being able to make decisions not by explicitly programming and supervision can be termed as machine learning. Here the machine is a system of several sensors which are fitted on the vehicle and gives out the input to the computers as raw form of data and system analyze the data and produce the results by applying various algorithms and concepts related to machine learning. The vehicle system helps in understanding the data and make its own decision as trained and helps in achieving the autonomous driving system.

11.1 Vehicle understanding and Learning methods:

The system in the vehicle helps understanding the raw data provided by the various detectors and sensors by various methods and learning.

11.2 Unsupervised Learning of Vehicular System:

This helps in using the patterns in the input data and classifies the data without any prior knowledge of data where it belongs to.

11.2.1 Reinforcement Learning of the Vehicle system:

The reinforcement learning is to learn by trial and error method. Through a series of rewards and punishments to maximize or minimize the long-term scalar value.

11.2.2 Supervised Learning of Vehicular System:

The system here takes the input data which vehicle sensors had never produced in the form of the raw data and this raw data is used in approximation and predicts the output variables of the data and gives a possible number of optimal solutions.

11.3 Artificial Neural Networks used by autonomous Vehicle System:

The different sensors and detectors in the vehicle system produce various kinds of raw data and it helps in producing the patterns by having unique features and properties. All these features are provided to the artificial intelligent system of the vehicle. The Artificial neural network is a computational network system which consists of multiple layers interconnected with output layers through one hidden layer.

All the hidden layers consist of the multiple nodes also called as neurons. These neurons conduct the dot product between trainable weights of neurons and give input values. After the dot product completes a weight is added to it which results in the activation function.

11.3.1 Activation Functions which help vehicle learn from the input data:

The mathematical operations are performed on the raw input data provided by the different sensors of the vehicle. All these mathematical operations are performed and used in artificial intelligent networks.

The following are the activation functions used to make the vehicle understand the input raw data:

11.3.1.1 Sigmoid:

The sigmoid (or logistic) characteristic takes an actual-valued number and maps it to a price among zero and 1. The most massive effect of the characteristic is that for massive fine numbers the output is 1, and for big negative numbers the output is zero. This impact ends in the very undesirable belongings of saturating the output to either 0 or 1.

11.3.1.2 Hyperbolic Tangent:

The tanh feature takes an actual-valued quantity and maps it to a fee between -1 and 1. Although its activations additionally saturate, not like sigmoid, tanh’s output is zero-targeted. Therefore, while designing an artificial neural network, the tanh feature is always desired to the sigmoid function.

11.3.1.3 ReLu:

The Rectified Linear Unit characteristic gives an output x if x is positive and 0 in any other case. Compared to the tanh and sigmoid capabilities that contain highly priced operations, ReLU can be implemented by really restricting a matrix of activations to zero. It additionally reviews fewer issues with vanishing gradients as compared to sigmoid or tanh that saturate in each direction. Some downsides with ReLU are that it is not zero-centered, nor is it differentiable at zero. Background can create issues with gaining knowledge of as numerical gradients calculated close to zero can be wrong

11.3.1.4 SoftPlus:

The softplus (or analytic function) is a differentiable approximation of ReLU. It has similar properties to ReLU but comes with a higher computational cost during training.

11.4 Training the artificial intelligent system in the vehicle system:

The education segment, the ideal output values for corresponding input values are regarded in advance. These acknowledged values are frequently known as floor reality. An artificial neural network is skilled through first creating an ahead pass of education data via the community, accompanied by way of an adjustment of the trainable parameters of every neuron through comparing how close the output of the network is.

11.4.1 Loss functions enabling the vehicle system to learn:

The loss function of an artificial neural network is a differentiable feature used to measure the inconsistency among predicted output values and ground truth values. It outputs a non-terrible real range wherein decreasing values represents increasing correctness of the network. It may be checked out as an illustration of a hilly landscape in the high-dimensional area of trainable parameters.

Here the input is given as the various values of the different sensors. And truth data and loss function. The loss functions which we use depends upon the kind of problem or the obstacle which we are about to face, or the vehicle is about to face. Depending upon the problem specific metric that should be maximized or minimized the functions are applied. The various loss functions involved are the following.

11.4.1.1 Mean Squared Error:

The system shall use the concepts of mean squared error in determining or predicting the results required to reduce the error I repeated iterations of the function to converge.

11.4.1.2 Mean Absolute Error:

The mean absolute error also helps in reducing error and converging the function to make the system help in making the prediction and thereby taking decisions.

11.4.1.3 Cross Entropy:

Cross entropy uses the logarithmic functions to reduce the error and helps the vehicle system to make predictions.

11.4.1.4 Hinge:

Hinge loss function also enables the system to make decisions by reducing the errors.

11.5 Data Preprocessing by the vehicle systems:

There are several sorts of data prepossessing which could affect the training overall performance of artificial intelligent neural networks. In the manner of training the network, the preliminary inputs are going to be improved with weights and motive activations that then can be used to educate the network with backpropagation and gradient descent. Therefore, it is far proper that each characteristic of the dataset have comparable properties, however with none biases like all tremendous values, to keep the gradients below control.

11.6 Deep Neural Networks enabling the Vehicle system to learn:

A Deep Neural Network is essentially an artificial intelligent neural network with or greater hidden layers. Since all trainable parameters of the community are found out with backpropagation, each hidden layer may be skilled to mechanically analyze representations of input facts with one-of-a-kind levels of abstraction. With the act of including more layers, deeper networks can represent capabilities of increasing complexity. In maximum practical deep learning events, the high-quality generalizing models are most customarily huge models (with many layers and a large range of trainable parameters) that have been regularized appropriately. There has been a tremendous growth in deep learning, mainly driven by faster more powerful computers, the availability of more massive datasets, and better techniques to train deeper networks. As a result, DNNs are beginning to be used in the vehicle system to detect the path and avoid the obstacles to make the ride smooth for the passenger.

11.7 Convolution Neural Networks enabling the Vehicle system to learn:

A convolutional neural network is a specialized type of Deep Neural Network mostly used when the input data has a grid-like structure, such as time-series data or image data. Although a convolutional neural network is capable of processing different kinds of input data, in the context of this thesis report inputs are assumed to consist of images represented by matrices with pixel values (or tensors for color images).

11.7.1 Structure of a convolutional neural network in vehicle systems:

The structure of a convolutional neural network is like any regular Deep Neural Network, with trainable weights and biases, weighted sums over neuron inputs with computed outputs through activation functions, and a problem specific loss function. The distinctive difference between regular Deep Neural Network and convolutional neural network lies in two convolutional neural network -specific layers called convolution layers and pooling layers.

11.7.2 Convolution Layers:

Just like regular completely related layers in DNNs, convolutional layers in a CNN may be visible as automatic characteristic extractors. The input of the primary layer may be a complete matrix of picture pixels, which in turn will be fed to a completely linked layer like in a normal DNN. However, due to the high dimensionality of a photograph, this would be very computationally expensive and unsustainable if the variety of used hidden layers grows. Therefore, instead of processing single pixels, a convolutional layer takes in square patches of pixels and passes them via a kernel.

11.7.3 Pooling Layers:

A pooling layer in a CNN can be perceived as a kind of down-sampling function. The function takes an activation map as input and outputs a summary statistic of nearby values from the input grid. Artificial intelligence thought exists in various forms to implement the pooling layers.

11.8 Algorithms enabling the Vehicle system to learn the patterns:

There exist two setup types of DNNs capable of accomplishing object detection in digital pictures. The first one makes use of an extra traditional approach which makes use of two networks working collectively. The first network is used to find areas inside the photograph with potential items, that is observed by way of a 2nd classifying community implemented on each of the proposals. The second kind treats the problem as a regression trouble the usage of sampling over unique places, scales and issue ratios and is all performed adopting a unified network to achieve the result. The first more conventional technique is generally greater correct however slower and is regularly referred to as a two-level technique, while the second one technique commonly outcomes in a faster but less specific version and is generally known as a one-degree approach.

11.8.1 One Stage Networks:

The deep neural network models in the forefront of object detection using the one stage methods mainly have different versions of YOLO (you look only once).

11.8.2 Decision Matrix Algorithm:

The algorithm analyses, identifies and rates the performance of relationship between the information and various values. All these information and analysis can be used in the process of decision making by the vehicle system.

11.8.3 Breakdown structure of the decision matrix algorithm:

The algorithm is extremely helpful in the autonomous driving vehicle system in making the decision such as to take the turns based on the confidence of the algorithms which does the recognition, classification, and prediction of the moving objects.

11.8.4 Composition of Decision Matrix Algorithm:

The decision matrix algorithm is the composition of various models trained independently and these predictions are combined to make the overall predictions by decreasing the number of errors while making the decision.

11.8.5 AdaBoosting:

Adaptive boosting or AdaBoost is a combination of multiple learning algorithms. These algorithms are basically utilized to offer the functionalities such as regression or classification.

11.8.6 Adaboosting resolves the problem of overfitting:

It overcomes overfitting when compared with any other machine learning algorithms and is often sensitive to outliers and noisy data.

11.8.7 Concept of Multiple iterations in decision making or classifying:

The adaboosting algorithms use the multiple iterations concept. By combining all the weak learner models, it forms into a strong learner. The weak learner is appended to the entity and the weighing vector is adjusted to pay attention to the samples that are classified incorrectly in the iterations done earlier. Adaboosting helps in the cascading of the weak classifiers and helps in behaving as the strong classifier.

11.9 Clustering Algorithms:

The different sensors used in the system are important in making the decision and images acquired by the cameras of the systems are key in object detection and in making the decisions. The images captured by the sensors are sometimes not clear and may.

11.9.1 Functionality of the Clustering algorithm in object detection:

The clustering algorithm helps in detection by using the regression and many methods like the regression. The clustering methods organize the data, categorize and report to the system and help make the classification.

11.9.2 K-means Clustering Algorithm:

The K-means clustering algorithm uses the concepts of centroids for the defining of the clusters. The sample or the observation collected by the sensors are placed in the cluster with the centroid based on the distance from the centroid of the cluster. By running the iterations of the k-means helps in the recognition of the objects and understanding the images captured to make the decision accordingly.

11.9.3 Pattern Recognition Algorithm:

The images or data obtained from the sensors in Advanced Driver Assistance Systems (ADAS) consists of all kinds of environmental data; filtering of the images is needed in determining the instances of an object particular kind by eliminating out the data points that are obsolete. Before classification of the objects, the recognition of patterns is an important step in a dataset. These types of algorithms are defined as data reduction algorithms.

11.9.4 Support Vector Machines:

Support Vector Machines are dependent on the concepts of decision trees that define the boundaries which in return are helpful in making the decisions. The decision hyper plane separates the object set consisting of distinct classes of data points or samples of an observation by the sensors in the vehicle system.

11.9.5 Regression Algorithms:

This algorithm is helpful in the prediction of the events or the samples. The Regression Analysis helps in the evaluation of the relation between two or more variables and collate results of variables such as different sensors producing the different results and samples on various scales and are driven mostly by three metrics:

11.9.6 Shape of the regression lines:

The images (camera or radar) play a significant role in ADAS in prediction and also in locating the vehicle, while for any algorithm, the greatest challenge is to develop an image-based machine learning model for feature selection and prediction by the system which helps in making the decision and object classification.

11.10 Various data in the form of dependent variables and samples of sensors raw data collected:

The repeatability of the environment is leveraged by regression algorithms to form a statistical model of relation between the given object's position in an image. The statistical model, by allowing the image sampling, provides fast online detection and may be learned offline. It will be extended furthermore to other objects without the need of in-depth human modeling. An object's position is returned by an algorithm because the online stage's output and a trust on the object's presence.

11.10.1 Number of independent variables:

The regression algorithms can also be utilized for short prediction, long learning. This kind of regression algorithms that can be utilized for self-driving cars are decision forest regression, neural network regression and Bayesian regression, among others.

11.11 Yolo Algorithm:

You only look once (YOLO) is a real-time object detection system which applies a single neural network to the full input image, hence the name You only look once.

Given a set of images (a car detection dataset), the goal is to detect objects (cars) in those images using pre trained You only look once (YOLO) model, with bounding boxes.

11.11.1 Image Classification with Localization by the vehicle system:

Objectives to discover the area of an object in an image with the aid of now not most effective classifying the image.

11.11.2 Object Detection for the vehicle system:

YOLO set of rules overcomes this difficulty by way of dividing a schooling photo into grids and assigning an object to a grid if and handiest if the middle of the object falls within the grid, that manner every object in an image can get assigned to exactly one grid and then the corresponding bonding field is represented by using the coordinates relative to the grid.

In the image, multiple adjoining grids may think that an object belongs to them, a good way to solve the intersection of union degree is used to find the most overlap and the non-maximum-suppression set of rules is used to discard all the other bounding bins with low-self-belief of containing an object, retaining the only with the highest confidence a number of the competing ones and discard the others.

11.11.3 Two Stage Networks:

In the two-stage networks, the first stage is the implementation of category-independent region proposals, followed by convolution neural networks feature extraction from these images and regions in the image. In the second stage category-specific classifiers are used to determine the category labels of the proposals. Most two-stage networks produce thousands of region proposals at test time, which comes with a high cost.

11.11.4 Faster R-CNN:

The two main two-stage based networks for object detection using bounding boxes, which have influenced the development of several similar networks, are Faster R-CNN. The R-CNN has a big influence on the development of new object detection networks based on the vehicle system.

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