Self-Driving Car Using Stereo-Vision And Anomaly Detection

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1 Introduction

1.1 Purpose

The main purpose of this software design document to describe the architecture and system design of our system Self-Driving car. The system is mainly about implementing a sensor based self-driving car that is able to make its own decisions while driving and detecting road anomalies. Our system is considered to be a device (car) that contains a variety of sensors to perceive the surroundings areas, lanes and objects. These sensors also identify appropriate navigation paths and take the lead in driving during the whole ride. Different algorithms and mechanisms are used to helps the self-driving car to take its own decisions safely[1],including Stereo-Vision depth calculation, accurate anomalies detection algorithm using Support Vector Machine algorithm to classify the readings of the road conditions from the sensors and use CNN to classify the images we of the road lanes and train the algorithm on them. The system is also developed to be a mobile application that receives the live updates of the actions that the car will do right before it happens to notify the driver in the car. We provide a fulfilled description about each single stage input, output and algorithms used. As we also illustrate the system components and how they interact with each other.

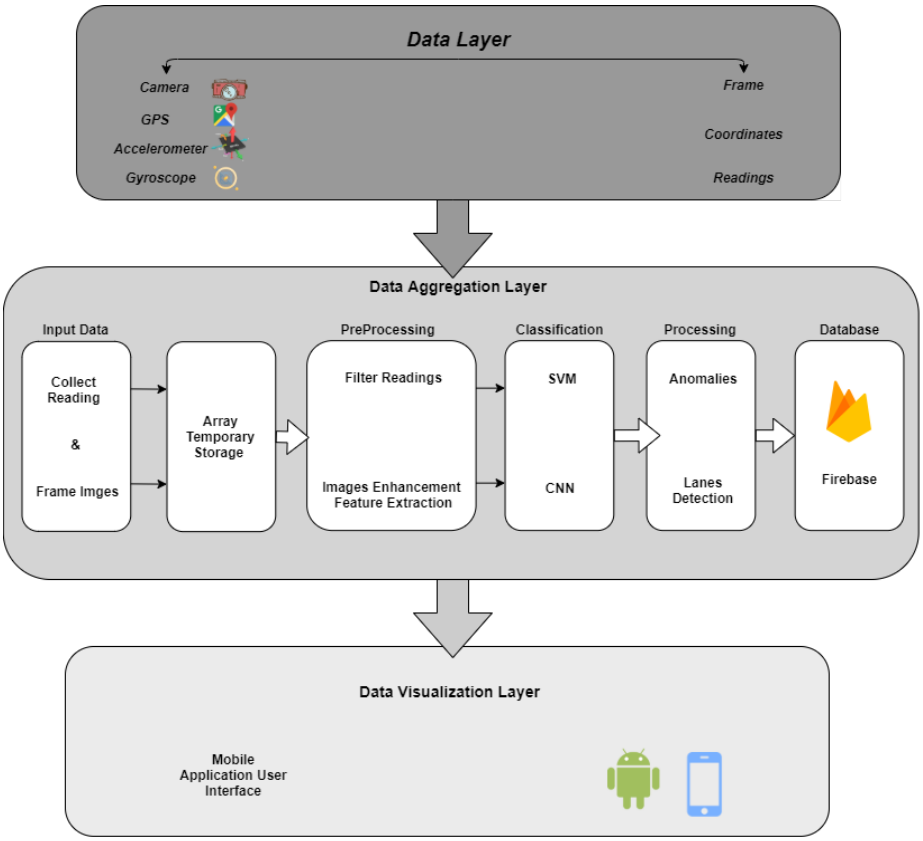
1.2 Scope

Our proposed system is an automated system that targets to improve and maintain safety conditions on roads while driving and decrease the rate of road accidents. Most Accidents are caused by a human error. A Self-Driving Car device is purely analytical that it acts like a smart computer, there won't be neither emotions nor distraction involved while driving because computers are faster and smarter to decide the right action than our mind. A Self-Driving Car is not only about maintaining safety for humans[2], but it is also beneficial in

maintaining the car safety as it is a recognition system that is applied to recognize and detect any road anomalies such as speed bumps and potholes then alerts the driver before hitting any. The system is responsible for collecting the data and calculate the depth map between the vehicle and the other vehicles surrounded. Then according to the collected data of the road anomalies the system is responsible for deciding the action to be applied, the path to be taken and highlight the road anomalies detected and saves its location then upload it to Cloud server. The system is able to alert the driver while driving (manually) with any anomalies that are not seen and alert to slow down the vehicle through the mobile application if a high speed or an abnormal behavior was detected[3].

1.3 Overview

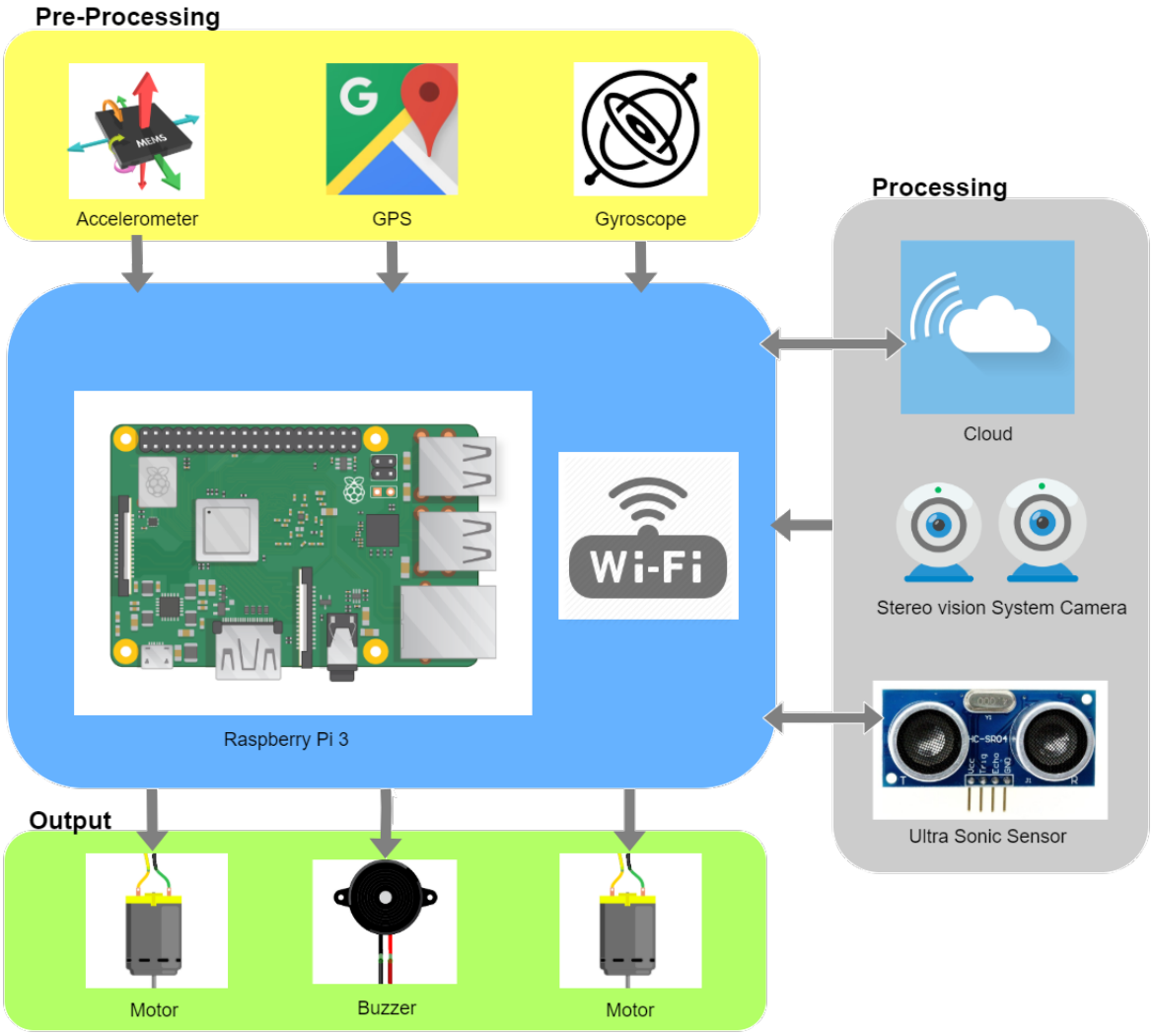
Our proposed system "Self-Driving Car" is an automated system that is about implementing a sensor based self-driving car that is able to make it's own decisions while driving and detecting road anomalies. Our project is considered to be a device (car) that contains a variety of sensors such as Gyroscope, Accelometer, GPS sensor and a dual camera to perceive the surroundings areas, lanes and objects. These sensors also identify appropriate navigation paths and take the lead in driving during the whole ride.



1.4 Definitions and Acronyms

Term	Definition
Ultra-Sonic Sensor	A type of sensors which generate high frequency sound waves and evaluates the echo which is received back by the sensor.
Gyroscope	is a device that can measure and maintain the orientation and angular velocity of an object elements.
Raspberry-Pi 3	A series of small single-board computers.
Accelerometer	A device that measures proper acceleration.
Stereo-Vision dual cameras	A type of camera with two or more lenses with a separate image sensor or video frame for each lens .
GPS	Global Positioning System.
SVM	Support Vector Machine is a model with associated machine learning algorithms that analyze data used for classification and regression analysis.
CNN	convolutional neural network is a class of deep neural networks.
MPU	Micro-Processing Unit.

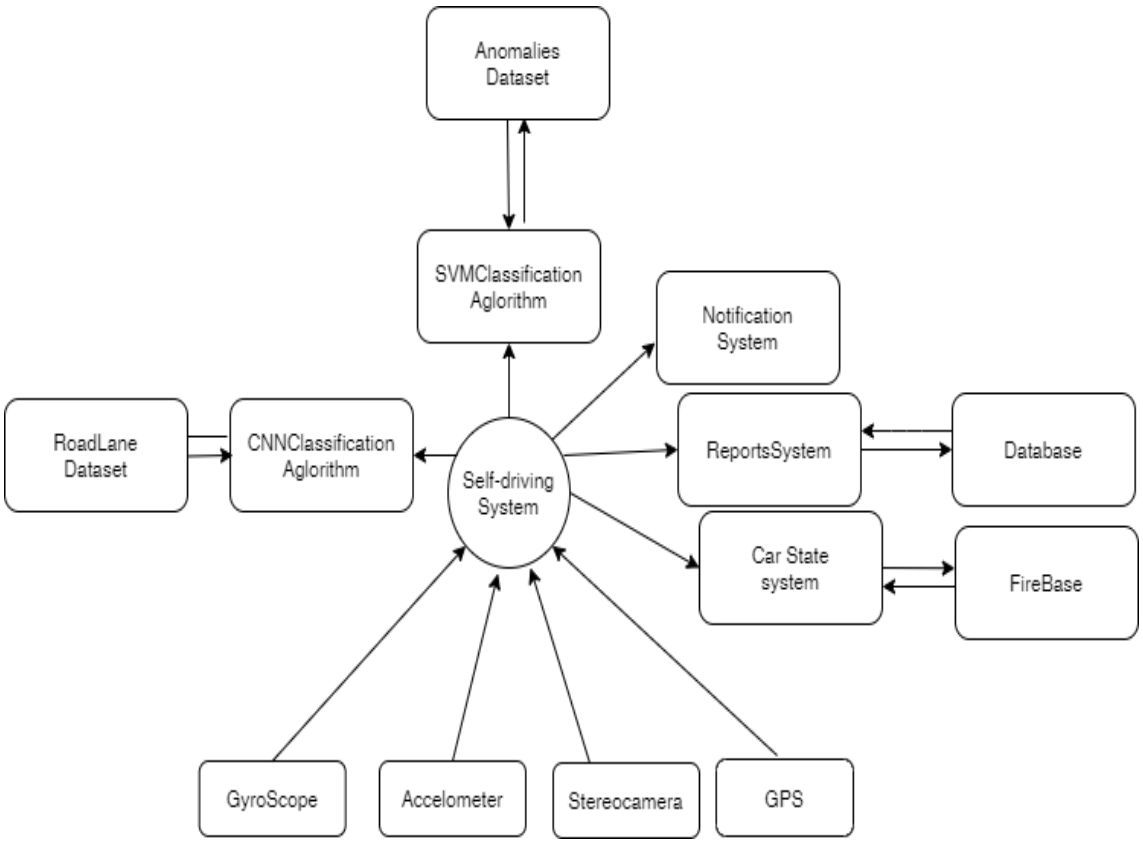
2 System Overview



Our car System overview consists of three main stages which are Pre-processing, Processing and output. The first stage is Pre-processing in this stage the sensors (Accelerometer, GyroScope, GPS and ultra sonic) are responsible for collecting the readings including video frames and data readings then filter them to remove noise. The second stage is Processing in this stage the Stero-Pi is responsible for using classification algorithms such as SVM and CNN on the collected filtered data. Bumps and holes location will be stored in cloud and the ultrasonic is used to help sensors reading in anomalies data. Stero-Vision is used to measure distance between vehicles and obstacles through disparity map.Finally, the Output stage is responsible for alerting the driver if anomaly detected through the

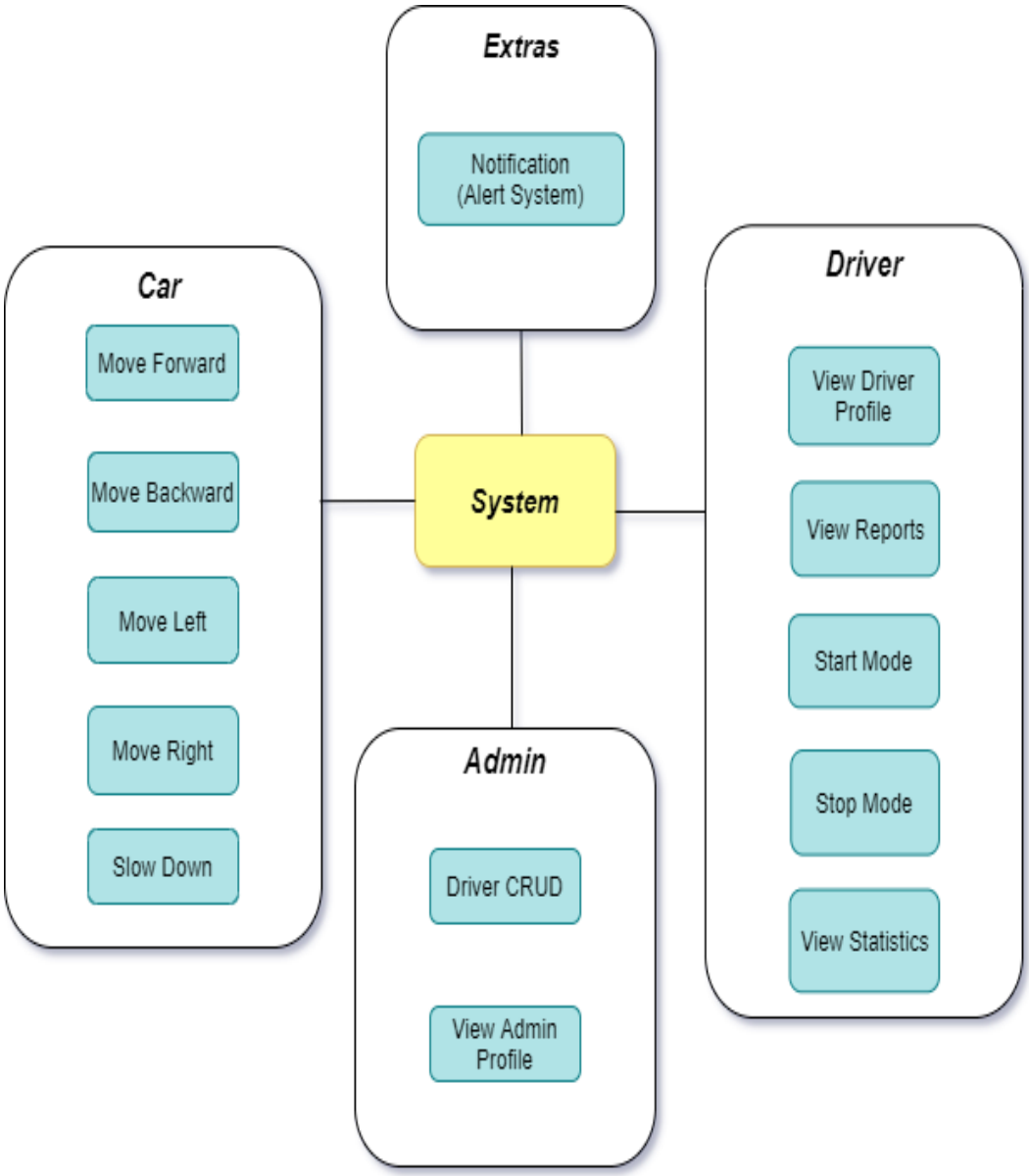
buzzer then the motor has the ability to take the decision of slowing down or changing lanes and detecting anomalies and avoid crashing with any obstacle.

2.1 Context Diagram

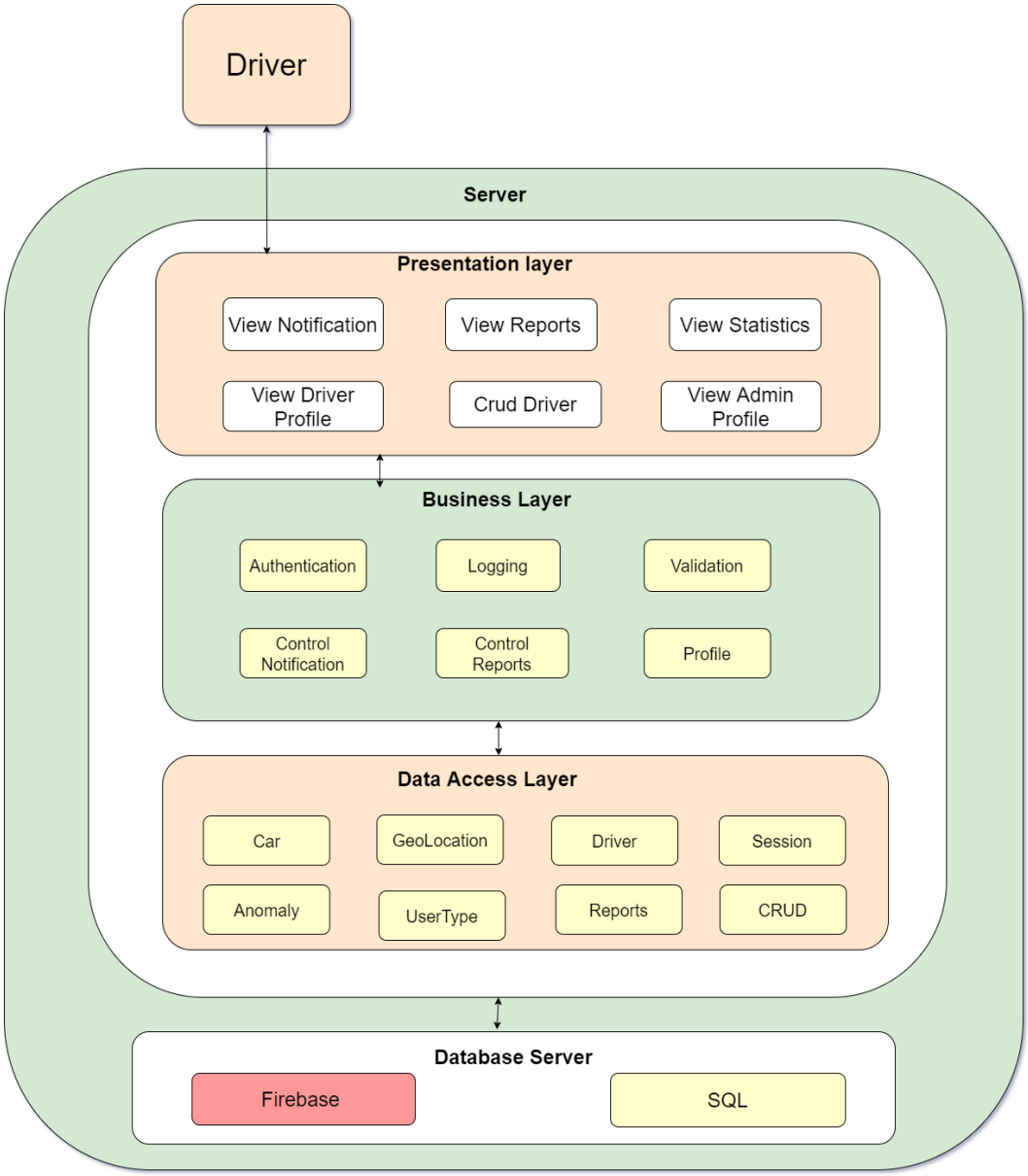


3 System Architecture

3.1 Architectural Design



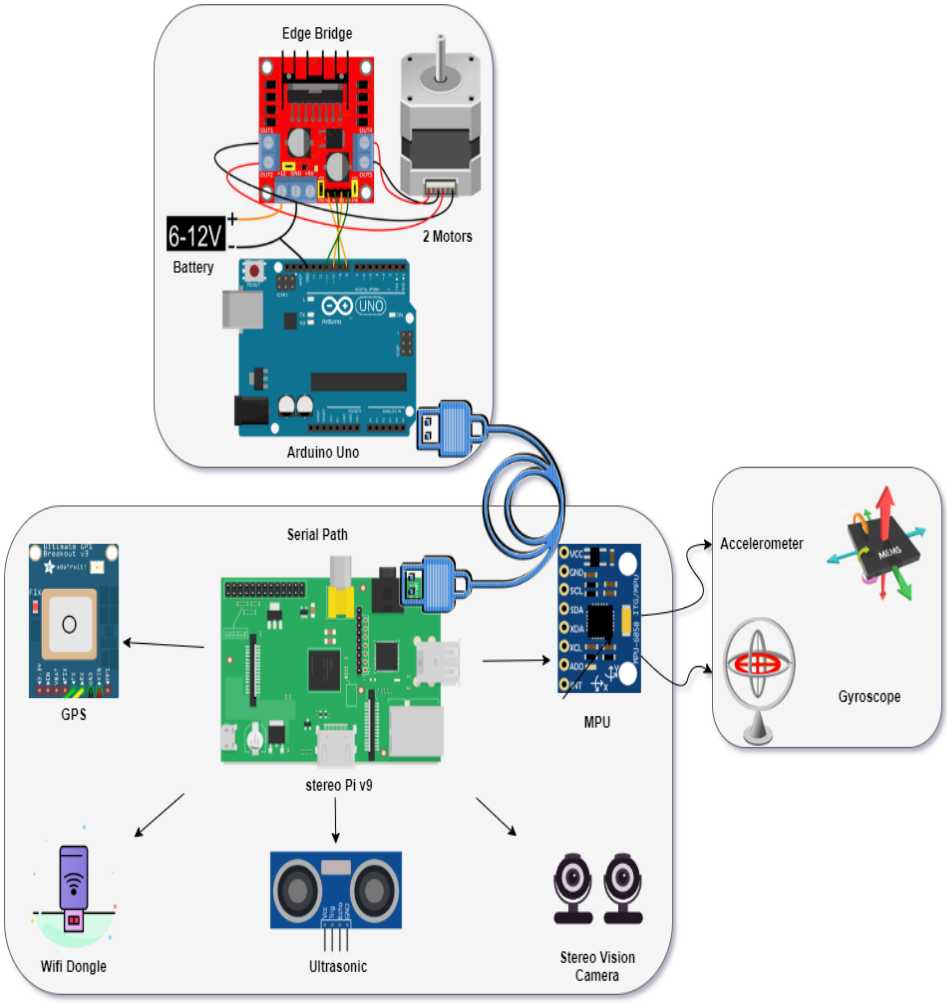
3.1.1 Software Architectural Design



The Software Architecture consists of 3 layer as it represents MVC Architecture, The presentation layer: it views the data to the driver and it has it's own function view notification : it alerts the driver of the current state of the car view reports: views the daily, weekly and monthly reports to the driver view profile view the driver profile himself crud: create , retrieve, update and delete driver data business layer: it connects between database and viewer which is

responsible for the authentication and validation also this layer controls Finally, The Data access layer that connects the mobile application with the fire base and database server also it retrieves the model state in the database.

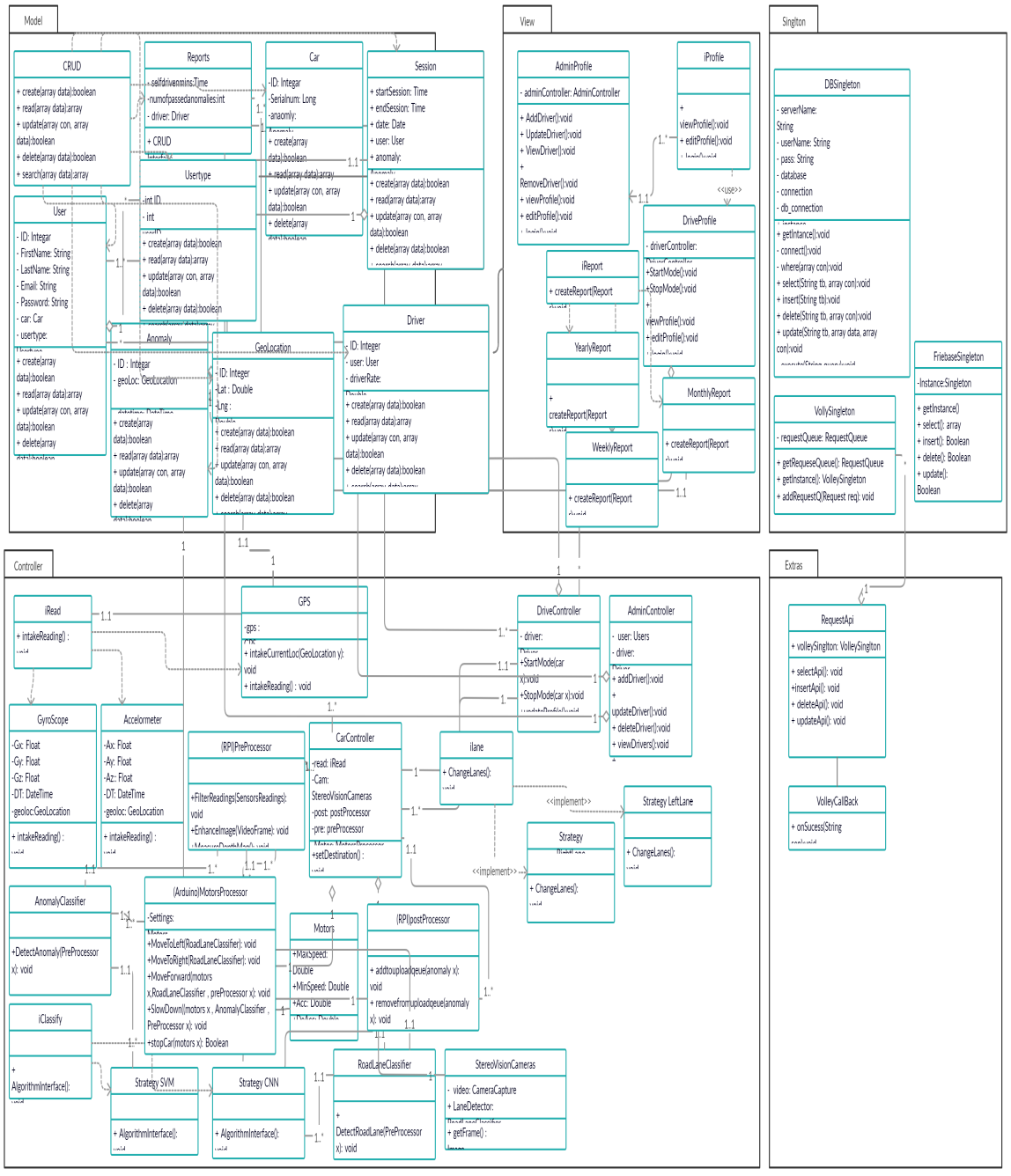
3.1.2 Hardware Architecture Diagram



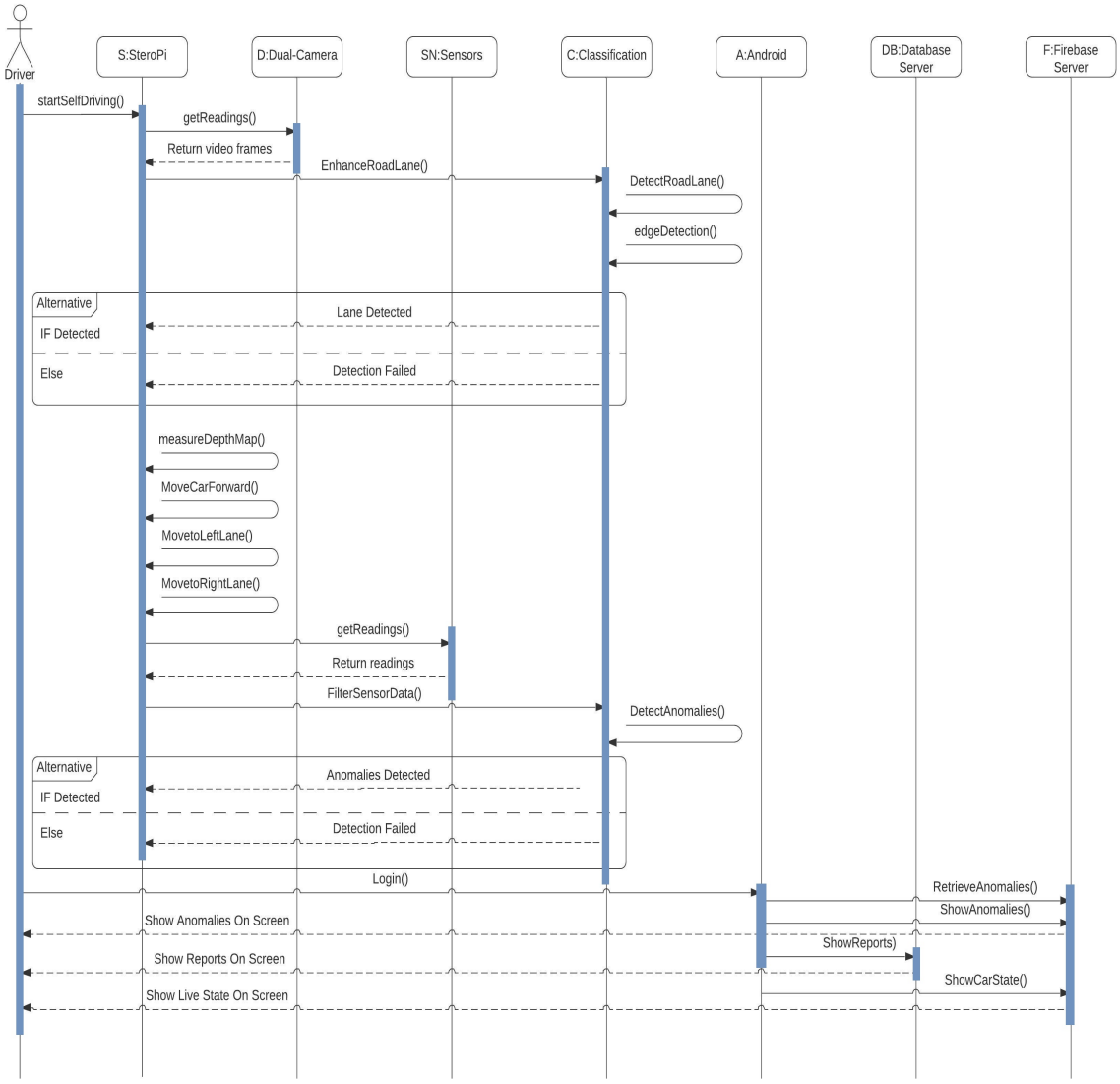
The Hardware Architecture that simulates a car simulation

3.2 Decomposition Description

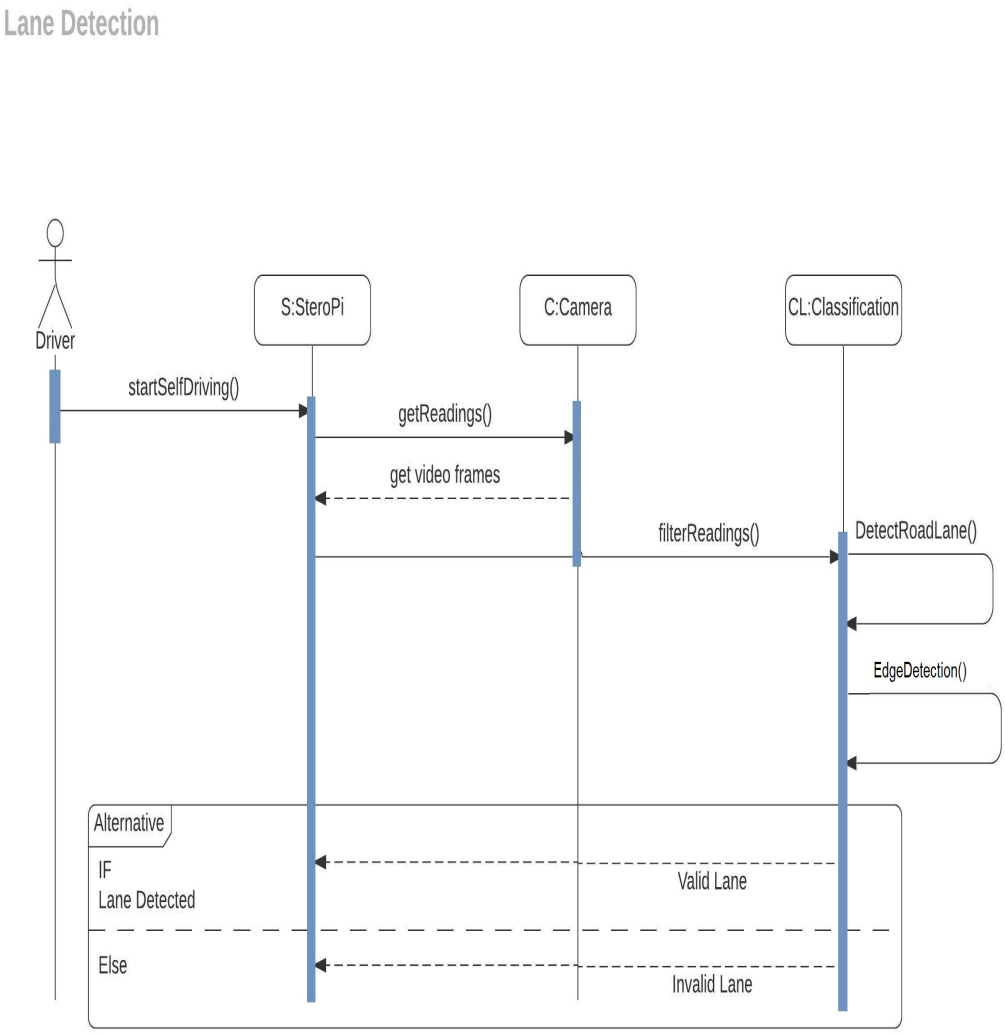
3.2.1 Class Diagram



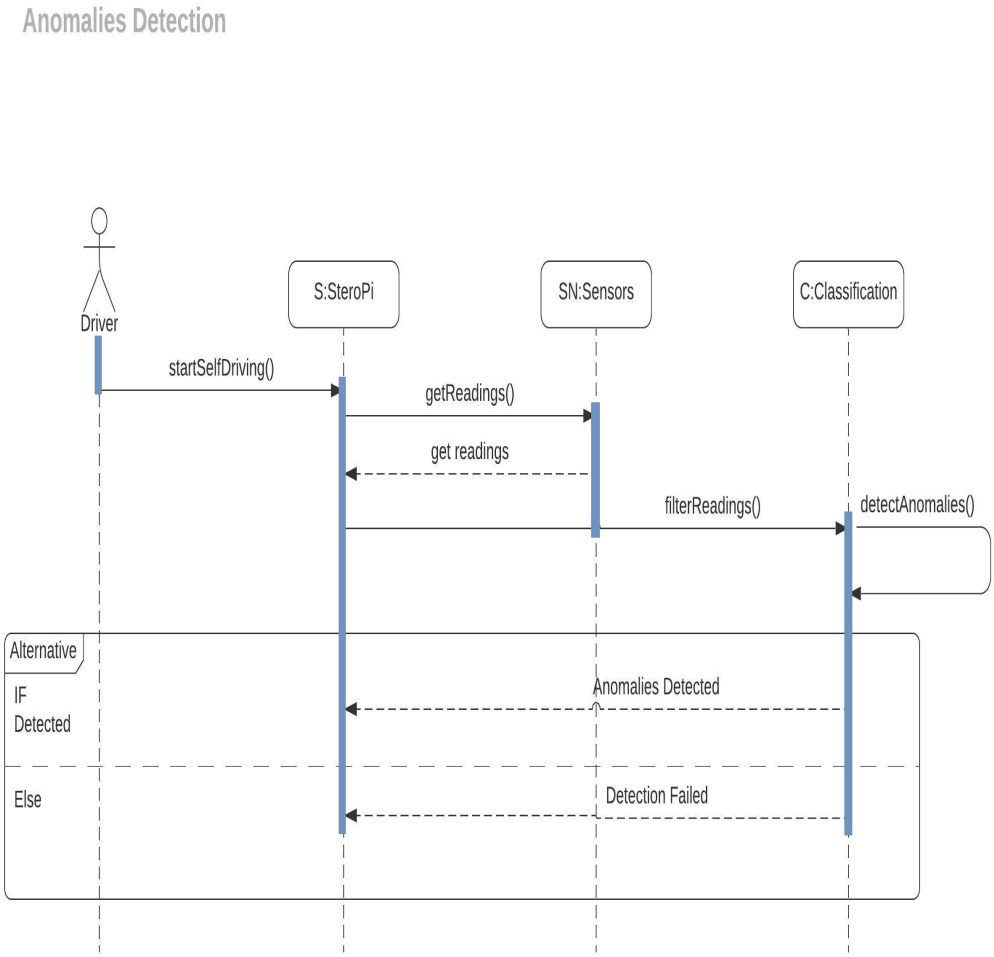
3.2.2 System Sequence Diagram



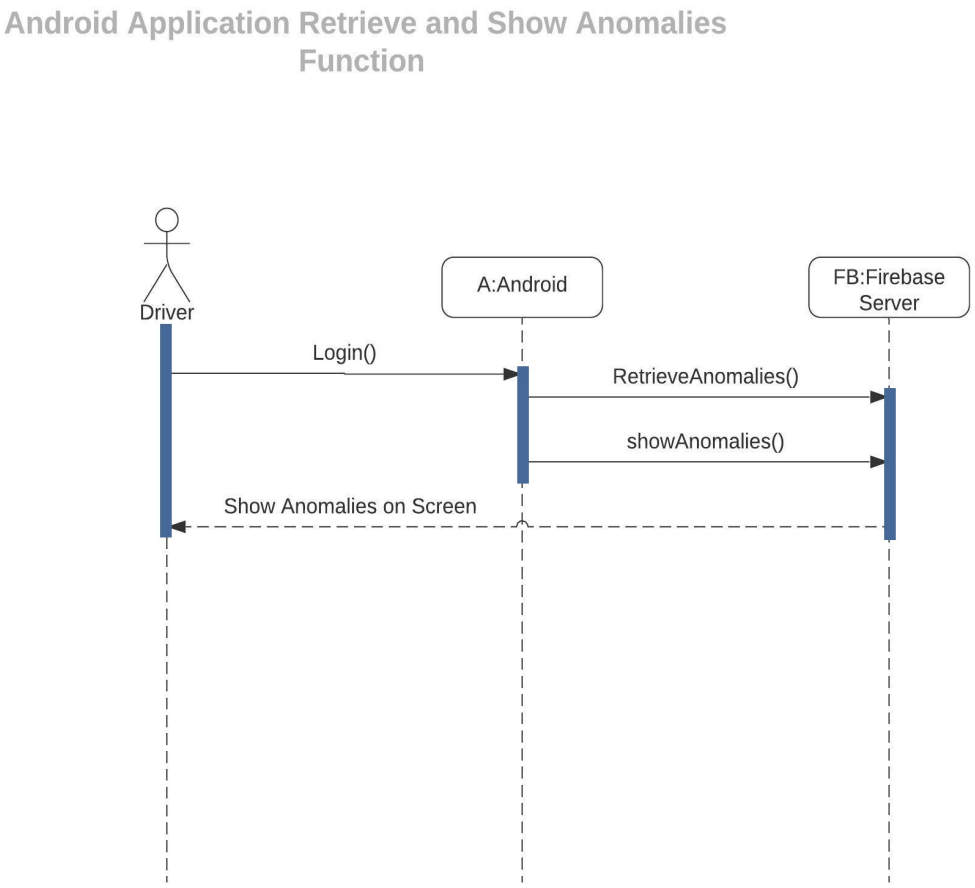
This sequence diagram is showing the entire system functions of our self driving car are interacting with each others in its right order.



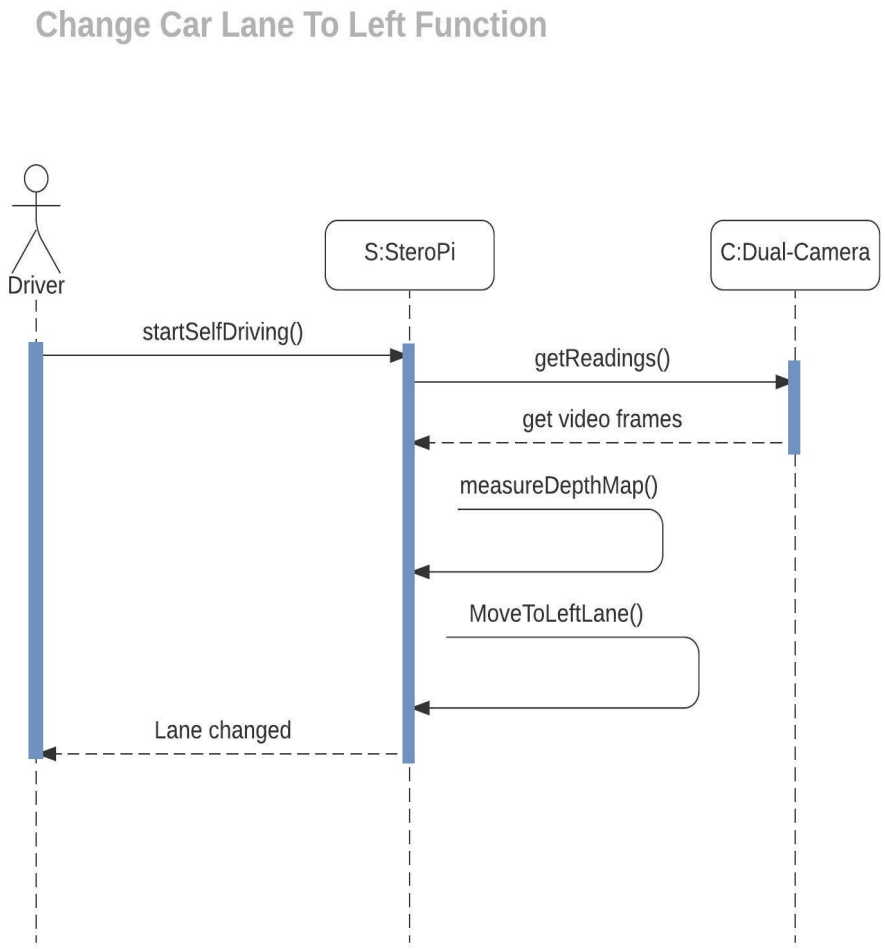
This sequence diagram explains the process of lane detection and how to apply it on our car using edge detection.



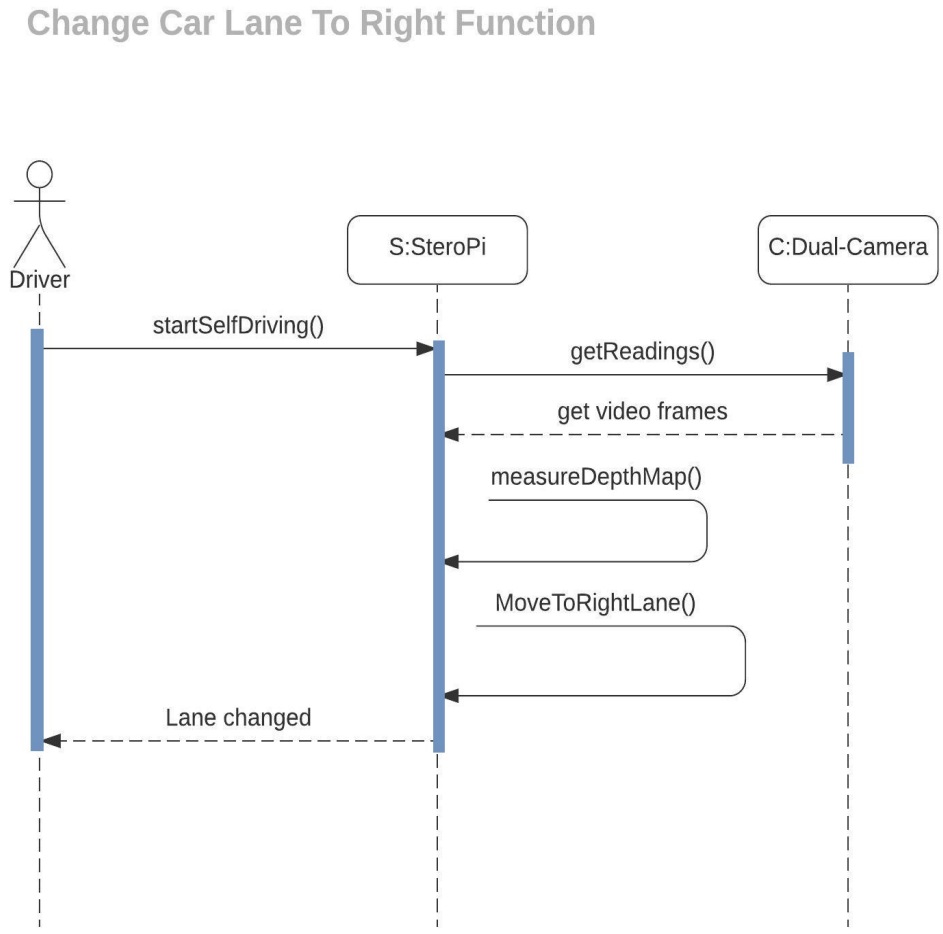
This sequence diagram explains how to classify anomalies and save it in our sever in real time.



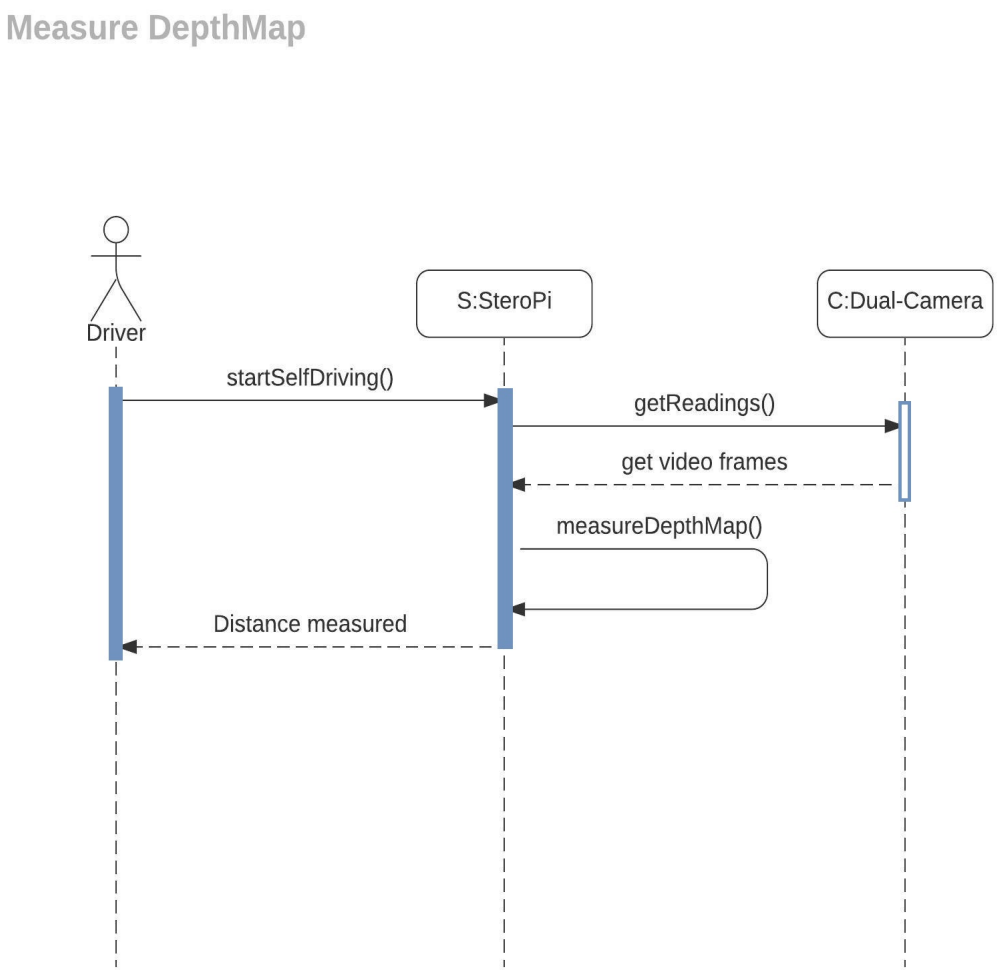
This sequence diagram explains how our application show and retrieve any anomaly after the car send its data to the mobile application and then the app shows this data in-details.



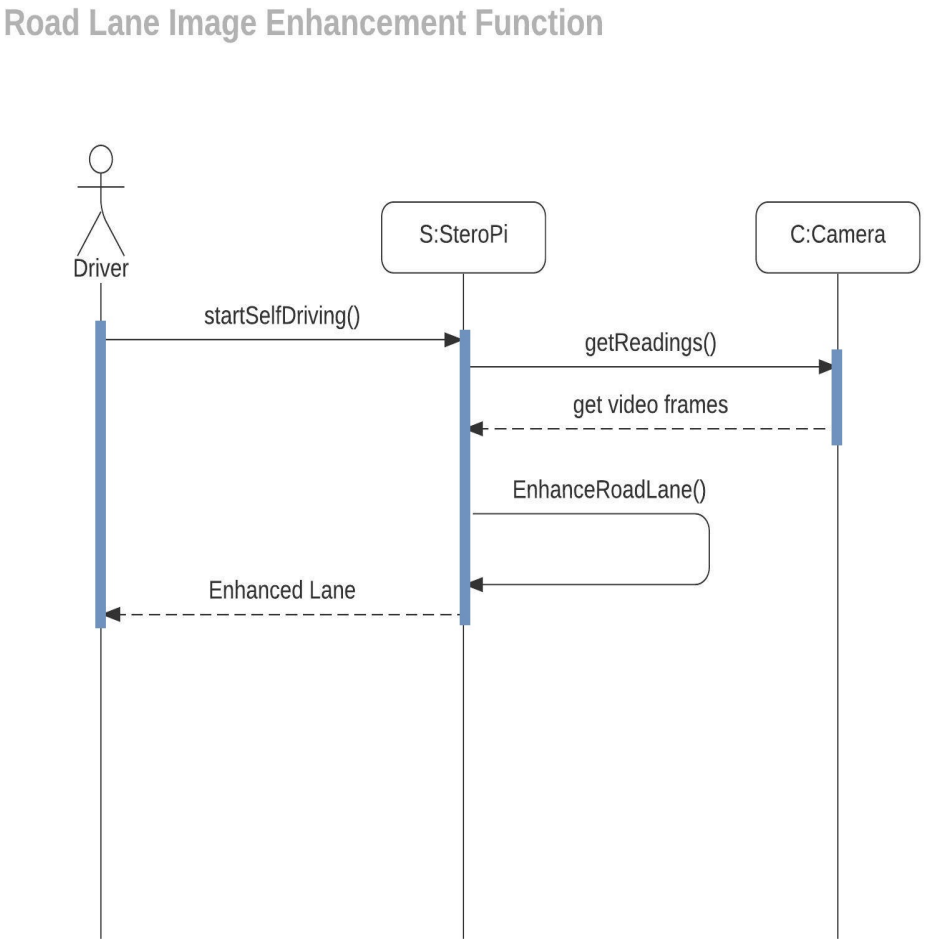
This sequence diagram explains how the car change its lane and in this diagram it specifically shows when the car change its lane to the left.



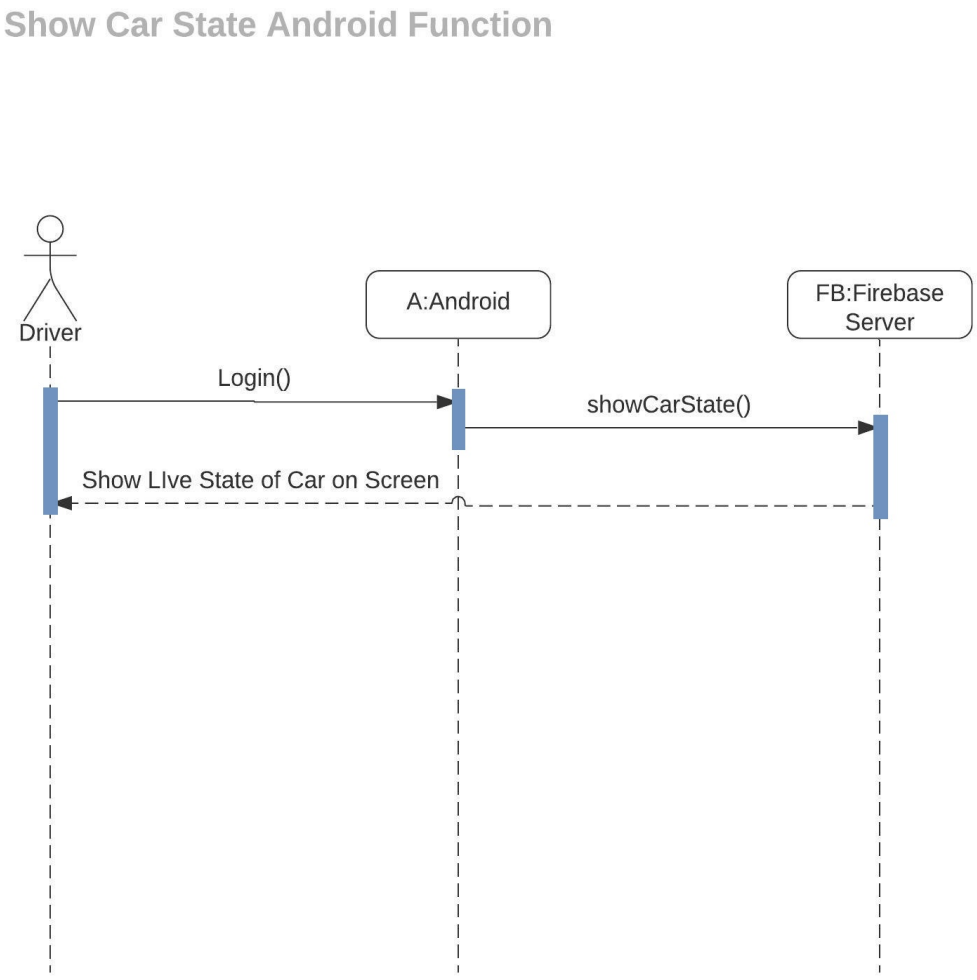
This sequence diagram explains how the car change its lane and in this diagram it specifically shows when the car change its lane to the right.



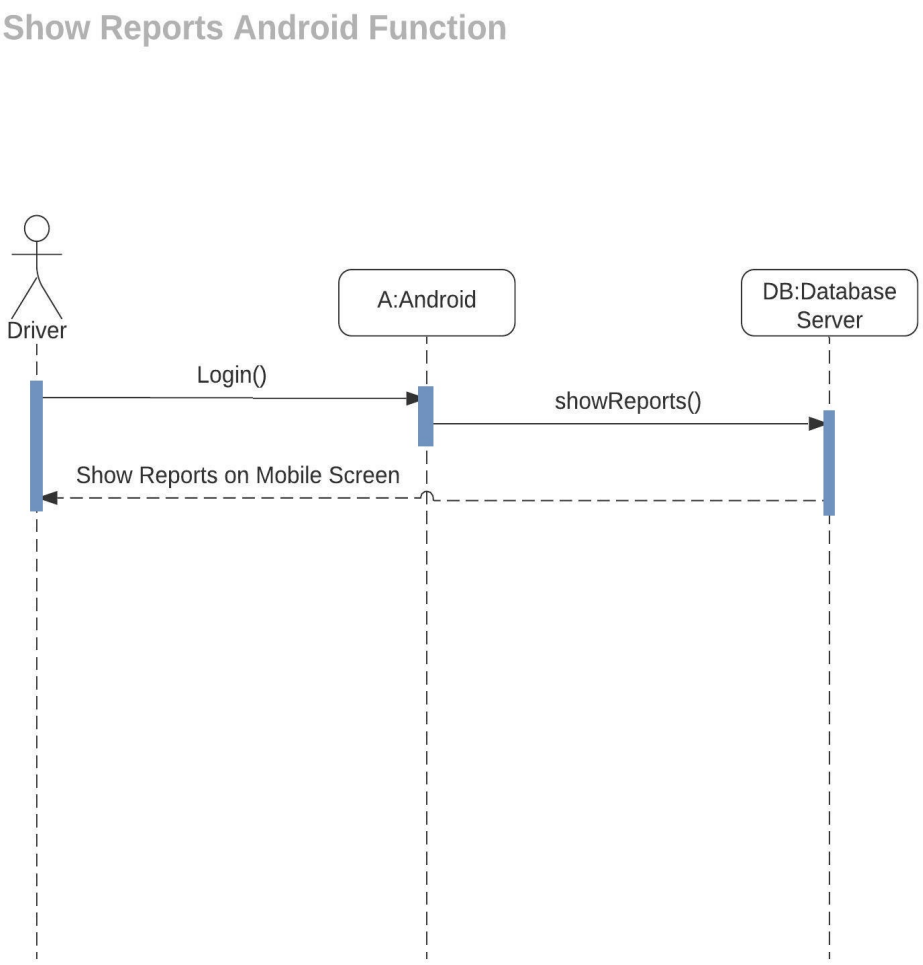
This sequence diagram explains how the measure the distance between the car itself and any obstacle in front of it by using disparity map algorithm, so it helps the car to take its decisions based on the obstacles in front of it.



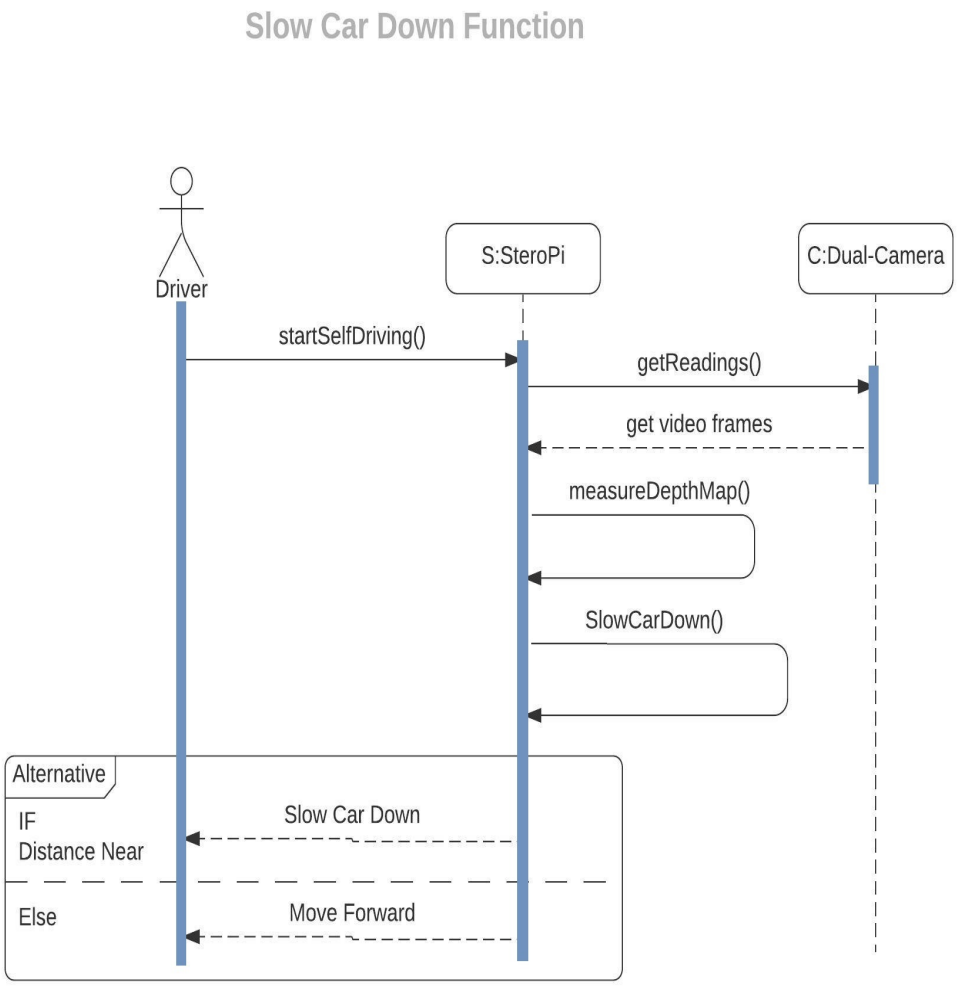
This sequence diagram shows how the process of enhancing our video frames in order to detect road lanes is being done.



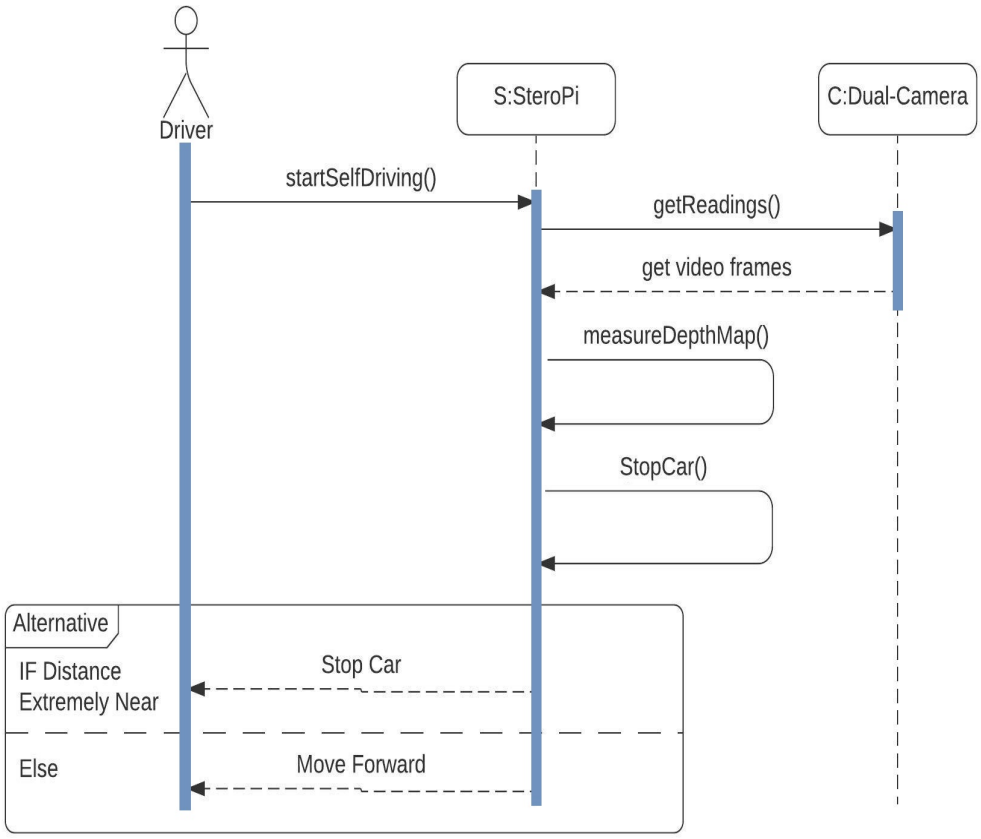
This sequence diagram shows how the current state of our car is being shown on the mobile application



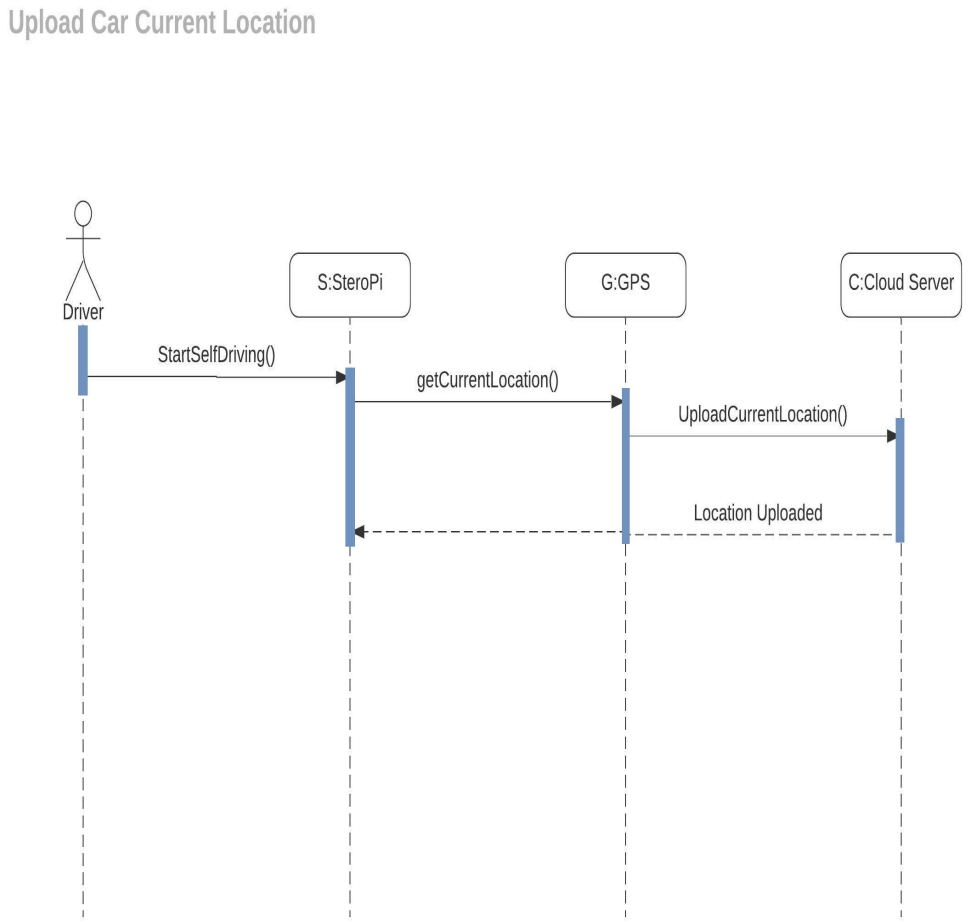
This sequence diagram shows how the reports are being showed in our mobile application.



This sequence diagram shows the process of how the car is stopped and under which conditions.

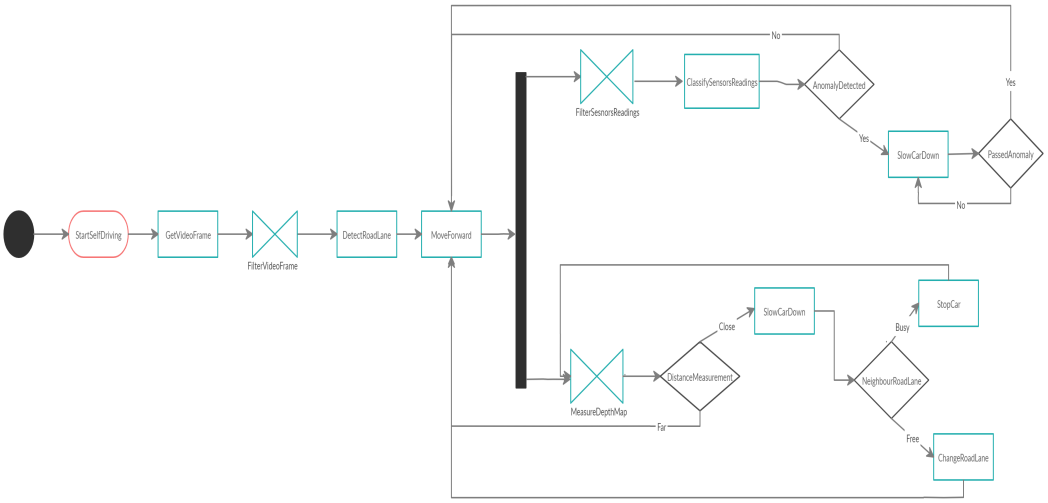


This sequence diagram shows the process of how are car is stopped and under which conditions.



This sequence diagram shows the process of how our system uploads the current location of our car to the server whenever its needed.

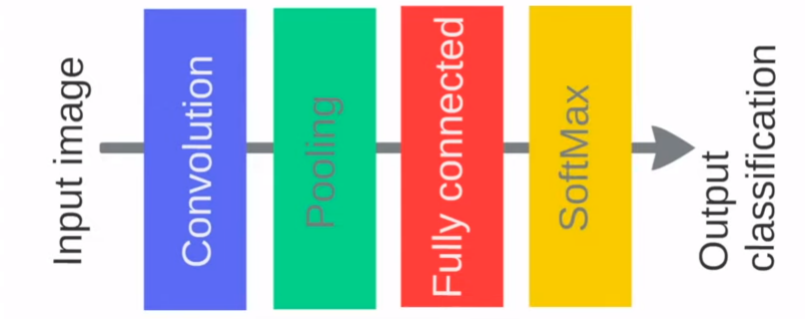
3.2.3 Activity Diagram



3.3 Design Rationale

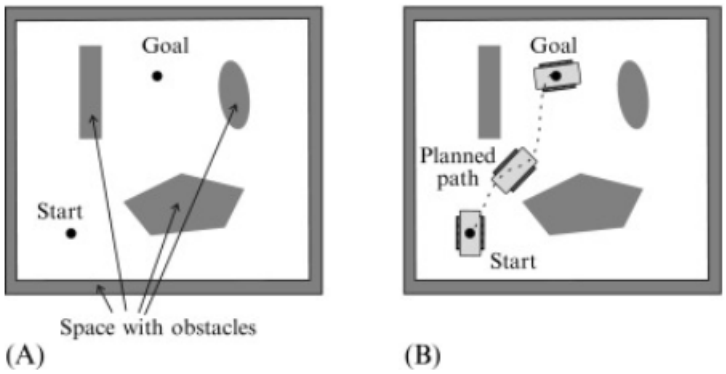
There are many algorithms used in the field of self-driving car and they must be accurate and reliable as this field is very sensitive and there is no room for error or delay. These algorithms are divided into two parts the first one is to detects the lane and the second part to detect the anomalies.

- Lane Detection
  - DNN: Deep Structured Network is one of the machine learning classes. It is dealing with high level extraction features, also it classifies digits and faces
  - CNN: Convolutional Neural Network is related to DNN class, it consists of input and output layers in additional to other hidden layers. Each layer passes the result to the next layer, also CNN is the most representative algorithm in deep learning model.



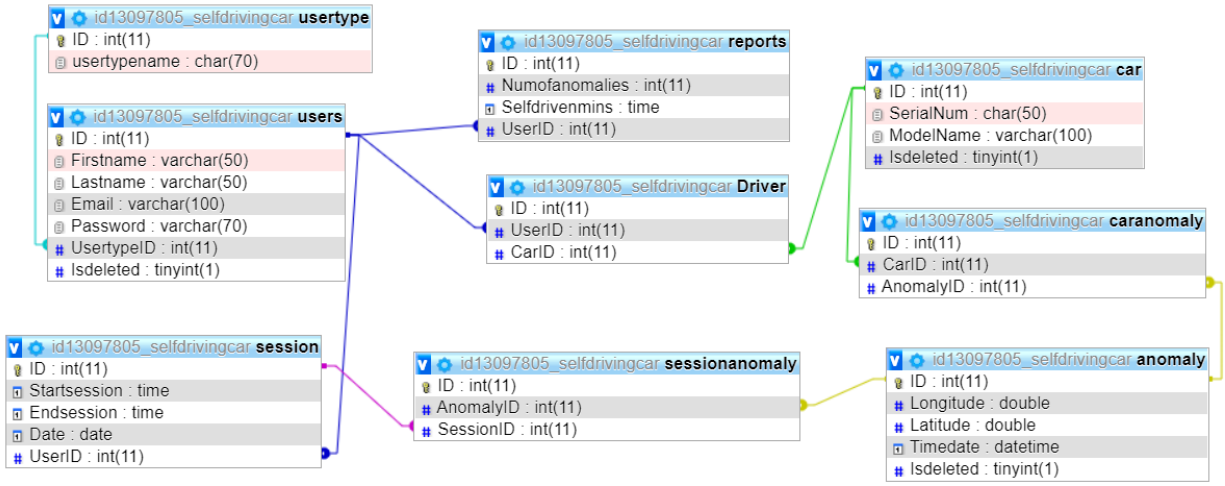
  - YOLO: You Only Look Once is a smart part of CNN, fast algorithm and gives high accuracy. It detects objects in real-time so by that yolo solves the problem of object detection in computer vision. Also this algorithm deals with the whole image and encodes it in testing and training.
  - Deep Q-Network: it is a combination between deep neural network and Q-learning.

- Anomalies
  - SVM: Support Vector Machine can accurately perfume non-linear classification, basically, it divides the data into classes and try to increase the distance between each class and to categorized each class with only some feature, so that the classification thing will be easier to differentiate between each class.
  - KNN: K-nearest neighbors it classifies the classes according to each neighbor, also it is known by lazy learning technique as it is only approximated to its nearest neighbor. In the training time the k-nn sorts the features. The accuracy of this algorithm is depending on the noise of each feature.
  - Bayesian Classifier: Naïve base is a scalable, simple and very efficient algorithm, but also it is not fully accurate as it doesn't care about the correlations between features in different classes.
  - DTW: Dynamic Time Wrapping it used to measure the difference between two temporal sequences so that this algorithm is mostly used in signature, speech and speaker recognition and also can be applied to videos.
  - Path Planning Algorithm: This algorithm used to determine the shortest path in dynamic environment while there are complex multi obstacles in this path. In additional to it can act with robot motion and adapt with any change in the environment. The most important advantage of this algorithm that it can adapt with known, partial known and unknown. environment.



4 Data Design

4.1 Data Description



4.2 Data Dictionary

User: A class that has attributes of : ID , Firstname , Lastname , Username , Password , CarID , UserID and has the details of the users.

Driver: A class that has attributes of : ID , UserID. that only represents the driver user and connected with car table as each Driver has a car.

Reports: A class that attributes of: ID , numberOfPassedByAnomalies , totalSelfDrivenMinutes , DriverID and connected with the driver table as each driver has his own reports

Car: A class that has attributes of: ID , AnomalyID and connected with the Anomaly class as every car capture their own anomalies.

Anomaly:A class that has attributes of:ID , Geolocationid , Date and Time and connected with the Geolocation class as each Anomaly has its own Geolocation.

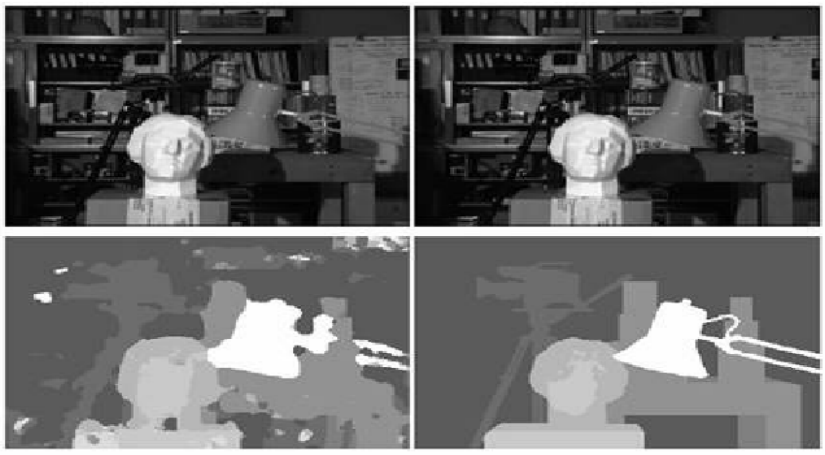
Geolocation: A class that has attributes of : ID , Longitude , Latitude. and simply has the data of the geolocation attributes on the map.

5 Component Design

Our self-driving car is mainly based on the disparity map, road lane detection and comes with it the anomalies detection. In order to successfully achieve both of them, we need to use the most efficient and accurate classification algorithms for both detecting road lanes and detecting road anomalies. So, we are using convolutional Neural Network "CNN" algorithm for classifying and detecting the road lanes in the video frames that we record from the cameras and Support Vector Machine "SVM" for classifying and detecting the road anomalies that we get from the MPU's" accelerometer and Gyroscope" readings as both of these algorithms have proved their efficiency achieving high accuracy in the road lanes and anomalies classification fields.

5.1 Disparity Map

We use stereo vision's disparity map as it's a better efficient way to know the distance between our vehicle and any other obstacle, car or whatever there is In front of the car that might stop it or cause a crash. Disparity map simply refers to the pixel difference between a pair of stereo images (video frames) that we record using our stereo vision cameras. It simply acts like human eyes, if a human closes one eye for a while and keeps on rapidly closing it while the other is still opened, the objects that are close to his/her eye will move a significant distance and the further objects will move a small distance. That motion is named disparity. So, Disparity will help us in this project achieving higher safety so the car will take its decisions based on the distance with any objects that comes closer to it. Either slowing down a bit till the object moves further, change its road lane if the other lane is empty or stops if there is no other option.



5.2 Convolution Neural Network "CNN"

We have used CNN due to its higher accuracy above some of the previously mentioned algorithms that classifies road lanes and images in general. CNN is like an automatic feature extractor from images which will save us the time extracting the road lanes features manually, also it's proven that CNN down samples the image which reduces its size first by convolution and then uses a prediction layer at the end "output layer" to predict the given image. The CNN algorithm in this project takes an input of an enhanced video frames frame by frame that only has the details of the road lanes in the image and classifying the road lanes using the trained model we have built to help the car move forward following the road lanes limits. The algorithm finally outputs if the image has a road lane or not. if the image does have a road lane according to the classifier. Lines will be drawn on this road lane so the car can move according to these lines.

5.3 Support Vector Machine "SVM"

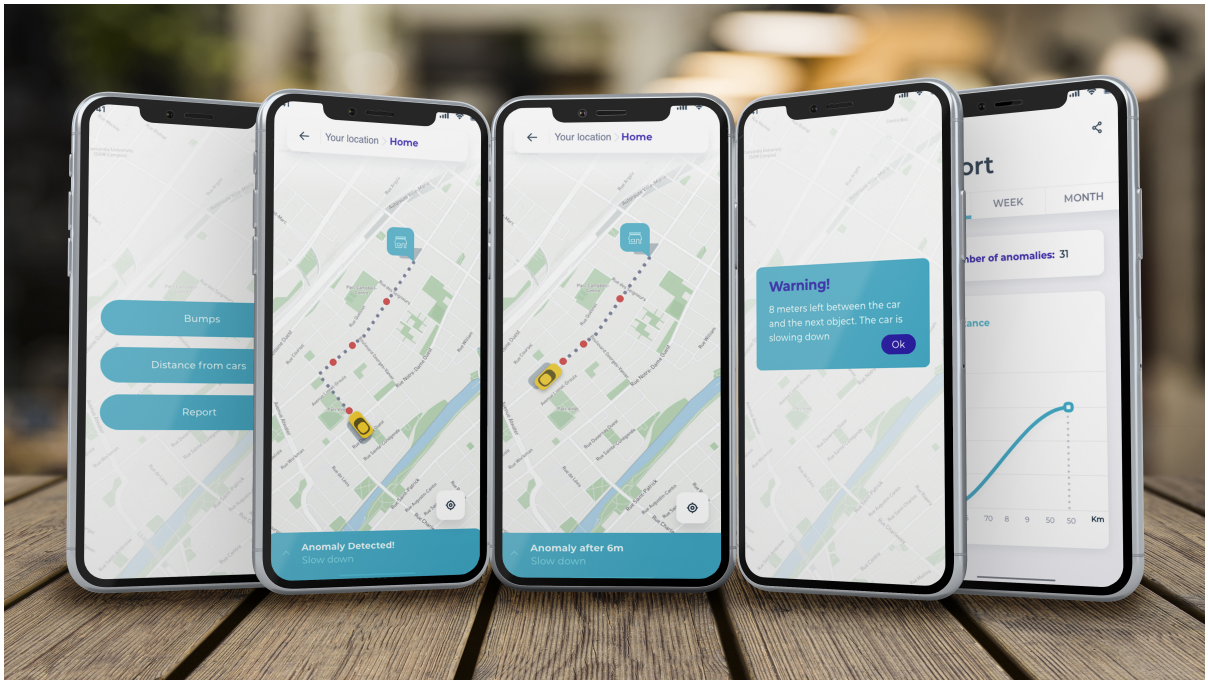
Also, we are using SVM in order to help the car achieve more safety for the driver while moving as we classify and detect road anomalies that the car passes through so it will slow down the next time it passes through the same anomaly location. SVM can capture much more complex relationships between our data points without executing some difficult transformations on the data on our own. SVM algorithm in the project takes an input of the accelerometer and Gyroscope filtered readings using a low pass filter and then classifies if the following readings are anomalies or not according to the data set we have. The algorithm finally outputs if the reading is an anomaly or not so we can upload its current location on our server if it was an anomaly using GPS. We have used SVM as it has been proven in many papers and projects with the comparison of other algorithms in the anomalies field that it achieved the highest accuracy and efficiency.

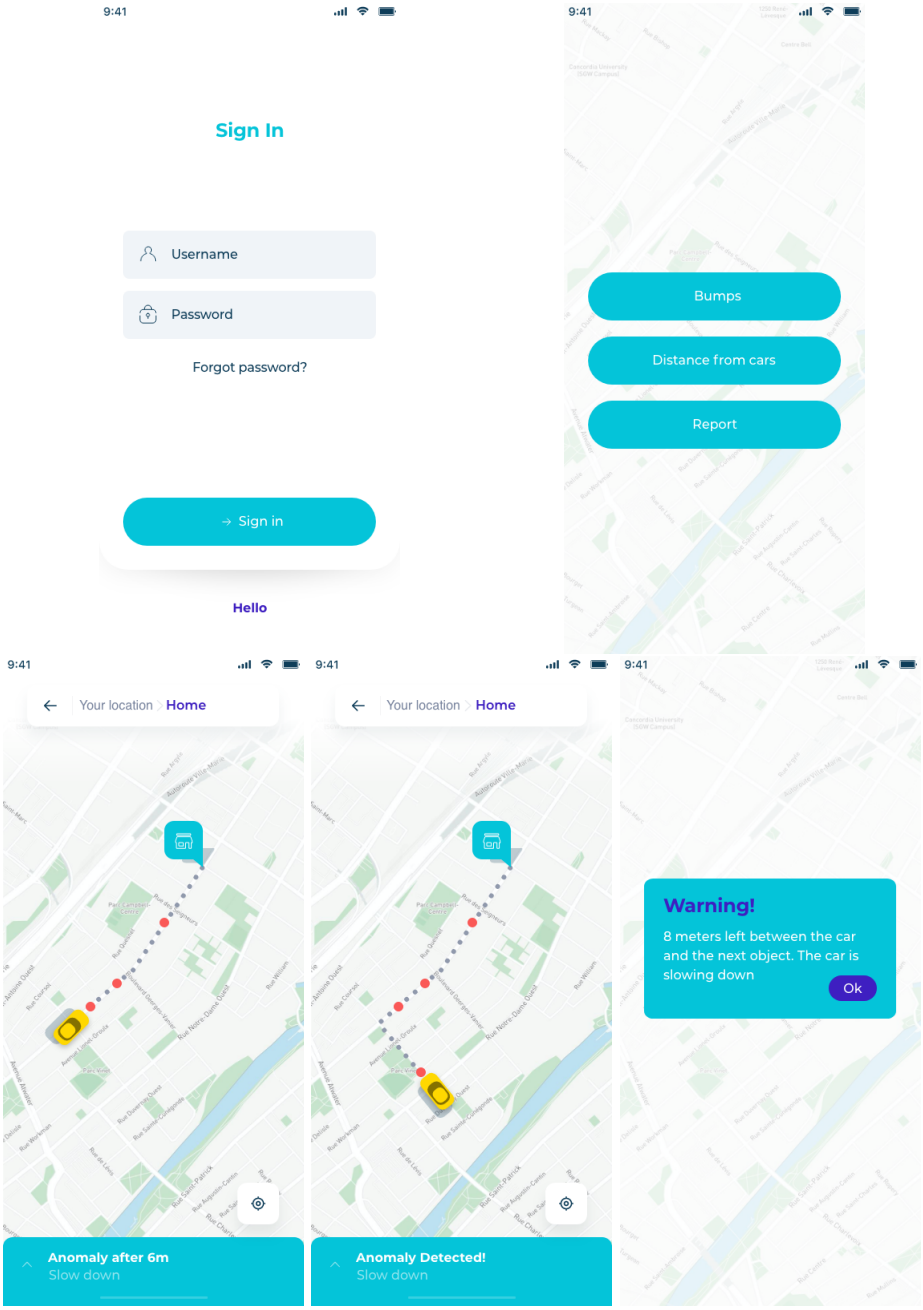
6 Human Interface Design

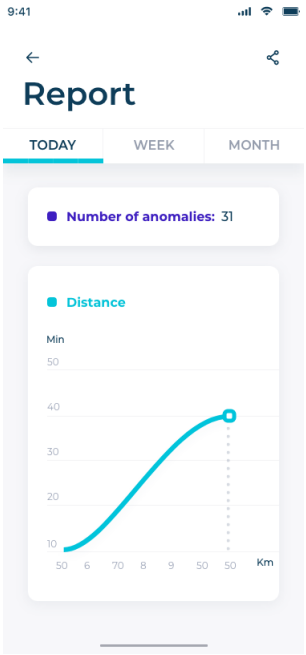
6.1 Overview of User Interface

Our system user interface is considered to be an android application which is very usable and clear to any user who can use smartphones. The system retrieves the anomalies state from the car, then alerts the user when detecting any bump or holes, also the system alerts the user before hitting any saved road anomaly and finally notify the user before slowing down or any sudden action so that the user will be relaxed. Furthermore, there is a report screen per day, week and month to show the number of anomalies which has been detected and a graph for the distance. The detailed user interface shown in the next section.

6.2 Screen Images




9:41
Sign In
Username
Password
Forgot password?
Sign in
Hello
9:41
Bumps
Distance from cars
Report
9:41
Your location
Home
Anomaly after 6m
Slow down
9:41
Your location
Home
Anomaly Detected!
Slow down
9:41
Warning!
8 meters left between the car and the next object. The car is slowing down
Ok



6.3 Screen Objects and Actions

- Retrieve the anomalies state from the car.
- view these anomalies to alert the driver that there is a bump or holes in front of him.

- Retrieve the distance between the car and any object.
- view this depth map between any object and our autonomous car to alert the driver.

It consists of three sections:

- Reports Per day
- Reports Per week
- Reports Per month

Then it shows the number of anomalies which has been detected and a graph for the distance.

7 Requirements Matrix

Req. ID	Req. Description	Description	Requirement Type	Status	Where In SDD
Req01	Login	Enter valid email and password	required	As Excepted	In Class Diagram
Req02	Road Lane Classification	classification and detection of the road lanes so that the car can move between the two lanes	required	Completed	In Class Diagram, Sequence
Req03	Anomalies Classification	Classify road anomalies to 2 classes bumps and holes and then detect them	required	Completed	In Class Diagram, Sequence
Req04	Upload Current car Location Coordinates Function	Uploads the coordinates of the current car to the cloud server	required	Completed	In Class Diagram, Sequence
Req05	Start Self Driving Function	Boot up the raspberry pie with all equipped cameras and sensors to perform their functionality	required	Completed	In Class Diagram
Req06	Change Car Lane To Left	Change the car lane to the left lane	required	In Progress	In Class Diagram, Sequence
Req07	Change Car Lane To Right	Change the car lane to the Right lane	required	In Progress	In Class Diagram, Sequence
Req08	Measure Depth Map	Measures the distance between our vehicle and the Obstacles in front using stereovision	required	In Progress	Class Diagram, Sequence
Req09	Slow Car Down	Taking Empty Array	required	Completed	Class Diagram, Sequence
Req10	Stop car	Stops the car after slowing it down based on certain conditions	required	Completed	Class Diagram, Sequence
Req11	Road Lane Image Enhancement	function that enhances and prepares the road	required	Completed	Class Diagram, Sequence

		lane image to be classifies			
Req12	Filter Sensors Reading	Filters the sensors reading to avoid noises	required	Completed	Class Diagram
Req13	Move car forward	The car moves based on the given Acceleration ratio and maximum speed	required	Completed	Class Diagram
Req14	Retrieve Anomalies	Retrieve data of anomalies from server	required	Completed	Sequence
Req15	Retrieve Distance	Retrieve distance of front cars from server	required	Completed	
Req16	View anomalies	View data of road anomalies from server	Not required	Completed	Sequence
Req17	View Distance	View data of distance from cars from server	Not required	Completed	
Req18	Get Video Frame	Retrieve each video frame to make enhancement on this frame to classify the road	required	Completed	Class Diagram
Req19	Get Readings From Sensors	Read data from Accelerometer and Gyro-Scope sensors	required	Completed	Class Diagram
Req20	Get Car Current Location	Retrieve current location of car	required	In Progress	Class Diagram, Sequence
Req21	Set Destination	Set the location where the car will head to	required	In Progress	Class Diagram
Req22	Alert Driver	Alert the driver when car is about to make sudden decision	required	Completed	
Req23	CD Anomalies To Upload Query	Add and remove the anomalies readings to/from server upload query	required	In Progress	Class Diagram
Req24	CRUD User	Add, Delete, Edit, View user	required	In Progress	

Req12	Training Session	If player started the training Session, nothing on the application can take place unless he finishes	Disable Application Functionalities	As Excepted	Completed

8 References

[1] Nugraha, Brilian amp; Su, Shun-Feng amp; Fahmizal,. (2017). Towards self-driving car using convolutional neural network and road lane detector. 65-69. 10.1109/ICACOMIT.2017.8253388.

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