University of Genoa

Department of Naval, Electrical, Electronic and Telecommunications Engineering

Gautam Ravindra Dange

A Gamification framework demonstrating a Complete Cycle of Vehicle Driver Performance Evaluation

Ph.D. Thesis

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Cycle XXX

Supervisor: Dr. Francesco Bellotti

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Contents

Abstract

Training through a gamified environment motivates the users in achieving optimal outcome and reduces the complexity of learning by adding factor of entertainment in it. The deployment of serious games in automotive industry is a major leap in technological grounds, as it's a best way to inculcate safe driving patterns to reduce the fatalities and enhance resource usage which includes car accessories and fuel. The Ph.D. thesis represents Gamification platform aimed to Green Mobility and Safe Driving. Good driving behaviour is a significant factor for road safety and green mobility. Thus, major tasks involve the evaluation of vehicle signals for analysing driver behaviour. How this infrastructure analyses vehicle driver performance, how information gets stored, processed and then further displayed graphically, statistically or in form of gamification, can be found in this thesis.

The Framework consist of 3 tier architecture, which includes Evaluators, Cloud running RESTful API services and Gamification Applications. Evaluators are either running inside Car or in a driver's smartphone. The Evaluators which are deployed inside car, called In-car Evaluators, do run in OSGi (Open System Gateway Initiative) Environment. The Evaluators which are run as Smartphone Application, called as In-Application evaluators. The In-Car evaluators use the raw vehicle signals for driver evaluation, whereas the In-Application evaluators use Mobile Sensors like Gyroscope, Accelerometer and GPS Data for evaluating a vehicle driver. For In-car evaluation the vehicle comprises of an OSGi environment, where the evaluators and signal receivers are deployed in the OSGi environment as Jar bundles. Vehicle Signals are transmitted from CAN bus to Vehicle Data provider bundles then to vehicle Data Consumer. The Different algorithms uses the signals from Vehicle data consumer for Driver Evaluation. The Scores, Events, time stamps and GPS latitude longitude information is sent to Cloud Server. The driver get evaluated continuously and partial results submitted to cloud server one every 20 or 30 seconds. The driver gets compared with peers, in context of competition, the driver who gets highest scores, gets ranked at the top, and gets incentives.

The Cloud server is a Tomcat Server deployed on google cloud. The MySQL database have relations which stores information about Users, Evaluators, Games, Application, Competitions, Competition Subscribers, Awards, Milestones, time-slots, Scores and Events. The Evaluators and Gamification Applications uses RESTful APIs for storing, querying, updating or removing in required contents. The Competition Manager tool is developed which allowed different Geographical and time-slots based competition. Once the vehicle driver subscribes for

the competition he/she automatically participate in the competition whenever he/she arrives at mentioned area in mentioned time-slots. The Gamification Application includes the application for checking out scores, Events and Incentives gained by the user. The Architecture provides and encourages implementation of serious games on the basis of Driver Performance. Using exposed RESTful APIs, game designer can access the user and his scores information on regular interval and can use this scores as an input to his/her game logic. This activity research activity was carried as a part of SG-CB (Serious Games and Community Building) module of TEAM (Tomorrow's Elastic Adaptive Mobility) project but had few different goals in parallel. Being in TEAM project thesis mentioned application, algorithms and RESTful API implementations had got tested on Car models which includes BMW sedan and Mercedes-Benz (s-class) & FIAT 500 at 2 different sites which includes ASTA (Active Safety Test Area), Goteborg, Sweden and Centro Ricerche Fiat (CRF) Turin, Italy. This project have got tested successfully under TEAL IP-7 and infrastructure encourages the games designer to use Serious Data for Gamification by providing Serious Gaming implementation platform.

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Disclaimer

I, Gautam Ravindra Dange (“the Author”), wrote this doctoral thesis in my personal capacity while studying in University of Genova, as Doctorate student.

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Acronyms and abbreviations

TEAM	:	Tomorrow’s Elastic Adaptive Mobility (European IP 7 Project)
SG-SB	:	Serious Games and Community Building
FOKUS	:	Fraunhofer Institute for Open Communication Systems
CRF	:	Centro Ricerche Fiat
HTTP	:	Hyper Text Transmission Protocol
OSGi	:	Open System Gateway Initiative
XML	:	eXtensible Markup Language
JSON	:	JavaScript Object Notation
JAR	:	Java ARchive
WAR	:	Web application ARchive
VC	:	Virtual Coins
VDP	:	Vehicle Data Provider (Service Bundle)
VDC	:	Vehicle Data Consumer (bundle)
PE	:	Penalty Event
REST	:	Representational state transfer
K-NN	:	K-nearest-Neighbour (Algorithm)
DSW	:	Dynamic Sliding Window (Evaluation Algorithm)
CAN	:	Controller Area Network (Vehicle supported bus for signal expose)
RPM	:	Rotations per minute (Engine load detection)
API	:	Application Programming Interface
GPS	:	Global Positioning System
BMW	:	Bayerische Motoren WerkeAktiengesellschaft (Car Company)

1. Introduction

It is always the driver behaviour that has the direct impact on all the factors that are concerned to efficient driving characteristics such as the road safety, fuel efficacy or the reasonable driving patterns. Also let it be the fatalities or vehicle collisions, it is again a genesis from the behaviour of the driver [9] [10]. As the driver behaviour holds a significant role in modelling the safe and green driving patterns, there are many models that are emerging under this roof. Providing necessary coaching to drivers under simulated environments would act as a test bed to facilitate the process of designing various safe driving methodologies [11]. Other approaches would be the prior and post analysis of driver behaviour with reference to the impact [12] [13], by predicting the outcomes and adjusting the current behaviour. However there is a mild patch between the simulation and real-world entity, most of the simulated results have to be adjusted to cope with the real-world situations. These safety and efficient driving measures must be approached from the perspective of system design [10], where the modelling must accommodate the dynamic environment. The major aim of my research activity is to inculcate the better driving practices using driver behaviour evaluation and social gaming scenario. This research activity was carried as a part of TEAM (Tomorrow's Elastic Adaptive Mobility) project [14].

For an early evaluation, data from vehicle signals collected in a test run conducted by Centro Ricerche Fiat (CRF) [15] in an area in the surroundings of Trento, Italy was used. As a viewpoint of my approach, the competitive gaming scenario would induce a good conduct in driving pattern and the evaluators used would ensure that the proper driving behaviour is exhibited. As the evaluators are comprised of four different approaches such as Linear distance to categorize the harsh and smooth driving patterns, and K-Nearest Neighbour approach to plot the relativity between the vehicle signals and to penalize the harsh behaviours attempted by the drivers whereas Dynamic Sliding Window captures the deviation from optimal level and track the events and Fuzzy based Dynamic sliding window to support same algorithm for different platforms without any change in code. Therefore the evaluators are designed to analyse various driving styles and fit to the context of the dynamic environment.

Most of the existing models in serious gaming context for automotive industry aims at improvising driver behaviour by various methods. But, there is another viewpoint for this approach (i.e.) out of many methods that could enhance driver behaviour, the chief methodology would be the qualitative driver performance analysis. I believe that, the first step in attaining better driver behaviour would be devising a qualitative evaluation pattern that would analyses and provide a detailed statistical report of driver performance. These analysis can be of great assistance in comparing the individual driver performance with the performance of peers, also the comparative analysis can be used for conducting serious games to inculcate the efficient driving behaviour. Having all these considerations as foundation, development of a comparative performance assessment schema that would analyse the driver behaviour on absolute and social comparison basis is noteworthy.

The connectivity and availability of transportation systems are increasing, and this enables the traveller to navigate to any destination comfortably. The types of transportation services are extended by more modern approaches like car sharing or rides. But although there are many possible ways to reach a destination, own transport is the preferred mode, because of comfort-ability and easiness. The use of the own car increases number of vehicles on road, which in turn contributes traffic congestion, air pollution and accidents. To avoid the increase of air pollution and critical accidents various solutions can be applied. One of these solutions is directly provided by car manufacturers. They aim to reduce fuel consumption, emission of cars, and increase of safety. One primary factor in reducing the air pollution and improving the safety is by altering the behaviour of the driver. If the driver is aware and willing to be follow better driving practices, the exhaust of pollution is low and safety is high. Otherwise if the driver is driving harsh or negligent, it will cause a high exhaust of pollution and safety risk for him/her as well as others. If one could influence the driving habits and awareness of a driver in an appropriate way, there will be a higher safety and a lower air pollution. Thus introducing an approach that will help individuals to drive in an appropriate way, e.g. to lower the air pollution and the risk of accidents. It is essential to convince the driver to stick to a better driving behaviour. The use of serious games approach can captivate the drivers to maintain optimal driving behaviour and by this methodology the drivers directly benefit by earning rewards. Every time the user showcase better driving behaviour, he/she will earn points and these points gets transferred as virtual coins to the user profile. The users can spend virtual coins on real-world applications (bus tickets, parking tickets, etc.). In general, the gaming approach may convince people to drive in an optimal way even if they would not consider about air pollution or safety issues.

The research has main objective of evaluating driver performance. Harsh or rash instances are fraction of single percent of whole driving, so, evaluation need to be penalty based. In the real time competition, whenever driver apply any harsh pattern, the algorithm detects this moves and assign a Penalty, for this pattern. This penalty will inversely affect his/her competition score. If Harshness of driving is significantly high, and driver get high penalty, then driver need to be notified about this behaviour with the details about date, time, harshness pattern and location where this harsh behaviours are observed, and few instant feedbacks also can be given to driver by acoustic notes. This process would be helpful making driver aware of his/her mistakes and reducing negligence.

The thesis explains the serious game building framework and narrates one demonstration of implemented example of a transportation scenario for vehicle driver performance evaluation. Firstly the explanation about Vehicle driver performance evaluation framework using RESTful APIs and Gamifications will be explained and then the idea of transparent evaluation and gamification methodology will be found in this thesis.

Project research activity of the PhD is about providing a gamification framework for game designers by providing a platform with which different game designers can develop serious games, without worrying about for which domain the serious game is created. The framework clearly distinguish between the serious information provider units with gamification unit which user this information. So, without the knowledge of real world understanding of the problem game designer can focus on score and period at which they with receive the score in numbers. Basically game designer will provide a username to the cloud with the frequency at which game score is expected, the cloud server will responds with the username and his performance considering the frequency of evaluation. Gamification can ask scores on a frequency which is lower than a frequency of evaluation, that is, if evaluation is sending data on every minute then game can't ask for 30 second interval, but can ask score on any other interval greater than 1 minute. Scores data not only gets stored on server as raw data, but server has different data structures and functions which calculates the score of hour using data of minute samples, and calculated daily data by calculating hourly samples in server in different data structures. This process allow different gamifications to use different periodic intervals to fetch the user data. For an example there can be a game called "Talking Tom". So Tom (Cartoon cat) game ask the server data of whole day performance of the vehicle user U, and with that score, Talking Tom shows different faces happy face, sad face or angry face. If whole day a drivers drives very optimal then Talking Tom can show his happy face on his game scene, or if driver applies some harsh brakes then at the end of the day Talking Tom would show angry face as a question on his driving behaviour. So basically game designers can implement any game with this data, by requesting server for the information which is in fact a serious information. At the same time, there can even more evaluators can be added for different comparative reason like person diet values. The connected framework would bring evaluation and gamification together using RESTful API calls, and framework will be responsible of providing evaluations related descriptions of period, score level, optimal score level and conversion of scales for different games according to their requirement.

Chapter 2 will discuss State of art in the domain of vehicle driver evaluation and serious games. Chapter 4 will discuss 3 tier Architecture of the proposed solution. Chapter 5 will discuss how vehicle driver performance is getting evaluated and its different types. Chapter 6 will discuss various sources which are used to get raw vehicle signals and which evaluators used to evaluate the performance. Chapter 7 will discuss about gamifications and performance visualizations for infotainment and serious games. Chapter 8 will discuss about a model, which automate the configurations required for vehicle driver evaluation. Also discuss about a platform which create a transparency between evaluators and games. This provides a facility by which game designer can create Serious game without knowing details of serious evaluation details given by cloud. Chapter 9 discuss about the experiments performed in Goteborg, Sweden and Turin, Italy. Chapter 10 discuss conclusions and possible future work in the domain respected to mentioned research.

2. State-of-the-Art

When designing a driver behaviour model there are many aspects that are taken into account such as data acquisition tools equipped with the system, extraction of vehicle signals based on the dynamics and most importantly the evaluation methods (algorithms) to process and analyse the vehicle signals to estimate the performance of the driver. To estimate the performance of the driver, [1] conducted an experiment involving in acquiring the time-series steering angle data during the lane changes by the driver. The experimental setup was under a controlled simulated environment and driver behaviour model was designed using conditional Gaussian model on Bayesian network and there was also a comparison along with traditional Hidden Markov Model. The final reports stated that, there were some minor problems in predicting the sudden changes in the environment, such as drastic change of steering wheel for dynamic happenings. Another comparison approach performed by [2] involved the estimation of driver behaviour model by implementing Gaussian mixture model and piecewise auto regressive exogenous (PWARX). The major task was the car following approach, where both of the probabilistic models outperformed each other on various occasions, for instance PWARX produced a good prediction in handling the Gas and brake pedal signals compared to Gaussian mixture model. However both of the algorithms performed well for the limited signals, as in the main focus was on gas and brake pedals only. The different approach that was implemented in car following task using Dirichlet Process Mixture [3]. The outcome stressed on the fact that, the metrics observed from this experiment can be a good step for future analysis in developing context adaptive system. These are some of the significant probabilistic models on current practice and let’s flip the side of the approach and look out the implementation of driver behaviour models using machine learning and adaptive algorithms. The ultimate challenge comes only when things are tested on the real-world applications in a rapidly changing environment, on such aspect the experiment [4] carried out by research team, comprised of “UYANIK”, a passenger car equipped with multiple sensors and CAN architecture for data acquisition was put up on real–world testing in estimation of driver behaviour. This was also a collaborative research conducted by NEDO (Japan), Drive-safe Consortium (Turkey) and the Trans-European Motorway (TEM), Istanbul. Almost the passenger car was equipped with all possible metrics to gather the signal, so as to make the prediction in an enhanced way. Post the data acquisition by CAN-bus, the signals were sent for processing to a SVM (Support vector machines) model, the labelled data were classified by SVM and the results of SVM were forwarded to a Hidden Markov Model (HMM), which performed the final prediction of driver behaviour. As the processing involved ample number of input signals, the classification and prediction using the machine learning approach was feasible by the system and the outcomes were formulated in an efficient manner. ANN was used as a major tool to classify the driving styles in various roads in the work carried out by [5].

The vehicle signals such as speed, engine RPM and acceleration were extracted and sent to the remote data centre, over there the analysis of data is performed by the neural networks. The ANN would categorize the types of roads (urban, suburban and highway) in which the vehicle was navigating and also the characteristics of the driver as well. However there exists various neural networks architectures, but only Multi-Layer Perceptron (MLP) is preferred predominantly [6]. Different architectures of neural networks must be experimented, so as to emerge out with better solutions for the problems in analysis tasks. On the basis of the state-of-art study on various driver behaviour modelling algorithms, there are many evident facts in handling the approach, firstly the probabilistic and mathematical models were considerably well on simulated and controlled driving environments and they exhibited a certain amount of error ratios and uncertainty when it came to real-world applications[1], whereas on other side the Machine Learning algorithms had the tendency to adapt to sudden changes in the environment and performed well with viable accuracy on all aspects such as classification, estimation and importantly the prediction. Another significant issue that has to be noted with respect to adaptive algorithms is, the incoming data signals should be more in number, because that particular aspect makes the task of evaluation a better one. It is also necessary for the evaluation parameters to hold the ability to adapt to environments, as most of the implementation happens on real-world applications. So it's always necessary to design the system architecture with reliable model that would facilitate for the varying environments.

The application of Serious games in various domains such as military [29], corporate [30], healthcare [16] and driving [17] have created huge impact in educating and training people though a gamified environment. Indulging in serious games environment can significantly improvise the skills of players such as decision-making, teamwork, leadership and collaboration in a controlled manner. The deployment of serious games in automotive industry is a major leap in technological grounds, as it's a best way to inculcate safe driving patterns to reduce the fatalities and enhance resource utilities. Some models involving the games for supporting safe driving such as: the experiment conducted by [18] using a motivational method of displaying avatar on screen, which cheers the driver during good performance. Fiat Eco drive [19] an application promoted eco driving and iCO2 game [20] gathered driver behaviour data from many users for enhancing Eco driving. There were certain research projects centric on human-machine interface (HMI) for enhancement of driving modalities such as: Project COMUNICAR [25] comprised of human-machine interface (HMI) for managing the driver information system ranging from entertainment to environment safety and the Adaptive integrated driver-vehicle interface (AIDE) [24] project which addresses the behavioural and technical issues oriented to adaptive human-machine interface. The “I-GEAR” [21] project (incentives and gaming environments for automobile routing) used serious games to understand the driver behaviour by creating certain scenarios that driver would comply. Whereas, the serious games IC-DEEP was developed to assess driver performance using in-vehicle Information System (IVIS) for tracking the distraction in driving process[22] and IC-DEEP was also used to test an Advanced Driver Assistance Systems(ADAS) to attain cost effectiveness in testing process[23].

The advancement in automotive industry comprises of numerous embedded applications (in-vehicle devices) to facilitate the driving experience as pleasant and safe for the users. The abilities of these in-vehicle devices are limitless and one major factor that has to be addressed over here is, what are the implications of these devices on the users (drivers)? Because, it’s the ability and tendency of the driver that determines the road safety and environmental aspects to a greater extent and also, the inadequate driver performance incurs many fatalities and chaos amongst the road users [31]. So, this factor gives an emergence and a need for the in-vehicle systems (equipped with the user-friendly framework) that will foster the green and safe driving abilities to disarm the on-road hazards. As it’s important for an in-car HMI (Human Machine Interface) to provide the drivers with comprehensive information to aid in safe mobility [32] [33]. The training process will induce the knowledge and awareness to driver about the driving circumstances and for this motive, use of serious games concept and smartphone utilities were perfect match. Serious games are a purpose based tool rather than an aspect of entertainment [34] [35] and they are widely used in various sectors such as education, military, healthcare and business [36] for captivating users to comprehend an information. Compared to traditional games that focus only on the engagement of the users, serious games does have a much higher responsibility, as it has to leverage and instil the concepts as well [37] [38]. An intense care and responsibility are needed in crafting a serious game framework and this leads to a prominent aspect of using *instructional design* (the use of technology and multimedia tools to enrich the informative content). Projecting a serious game concept through an instructional design (representation on HMI) promotes the higher degree of visual feedback for the user and this visual feedback takes a substantial effect on driving conditions [39]. Thus, to inculcate safe driving behaviour and establish a collaborative gaming structure, I developed a smartphone-based serious gaming architecture with diversified game logics to enhance the driver performance. The reference architecture is a Service-Oriented architecture [40]. The game logics act as an informative box that supplies the feedback to the users (drivers) in various ways such as scores, virtual coins (incentives that can be used on real-world entities) and live game for displaying the performance evolution. As the serious game provides a behavioural influence on driving, the constant impact of it will act as an emergence of optimal driving behaviour amongst the road users and benefit the environmental safety as well.

The task of educating or training through a gamified environment aims to simplify the learning process by adding a factor of amusement. Gamifying mechanism provides an interaction and engagement of users with the gameplay and this could motivate the users in achieving optimal outcomes. The process of gamifying a non-game context, provides a better learning possibilities for the users [43]. Usually the traditional games focus on the engagement of the users with the gameplay by delivering a good amount of interactivity and various properties on the game scene for entertainment. The serious games focus on providing information and training on some context or to instil certain concepts through a gameplay [44] [45]. Designing a serious game is highly challenging as it should seal the information and entertainment in the same box and required to be developed in a way that it is practically usable over the long run for the continuous development of the user. The core of serious game should be equally balanced between the information and entertainment, if there is an imbalance in this, then the informative content becomes trivial.

Usage of an instructional design (application of technology and multimedia) in crafting a serious game framework can be a significant aspect of a serious game design [46]. The incorporation of instructional design and serious games can enable higher level of learning outcomes, as the design will involve necessary game characteristics (competitions, goals, challenges and etc.) and learning objectives[47].With all these assets, serious games can be exploited in automotive domain to foster green driving (maintaining optimal driving behaviour constantly, without rapid harsh events). The driver behaviour has a major contribution in road safety and green mobility aspects. When analysing the driver behaviour, it’s important to understand the difference between the driver behaviour and the driver performance, where - the driver performance is referred as the abilities (such as skills, knowledge, and cognitive abilities) of the driver and the driver behaviour is the preference of driver from the experiences gained [48]. It's also a mandatory fact to concern about the safety, while developing applications that would captivate driving behaviour. These applications should also consider the aspects like driver distraction, immersion on secondary tasks and etc., which could grab driver's attention. Because, the involvement of drivers in secondary tasks while driving can cause on-road hazards [49]. So, one highly recommended target was to enrich the knowledge and awareness of the driver by an infotainment system, which manages to gamify the driver performance. I propose a gamified environment for drivers to promote green and safe driving, where drivers will not only improve their own performance but also can give a contribution for better driving practices of others in their region by designing their own competition with Green Driving or safe driving criteria's and by announcing some rewards. The framework allows this to happen in few steps and users need minimal actions to participate into these competitions. The game environment allows the player to visualize the performance on the game screen without direct user interaction to the game. This provides immediate feedback of the performance on game environment and the process of immediate feedback would cultivate a procedural learning [50] and enables user engagement [51] [52]. The immediate feedback also provides an understanding to the user about the driving performance. Especially, when driving behaviour is bad with more harsh driving events (such as: harsh brake, high acceleration and etc.,), the user can visualize a downfall in the game. Thus the impacts of driving pattern on gameplay helps the users to understand driving performance and improvise the driving behaviour. Incentivizing the user performance provides a motivation for the users to progress and improvise the driving traits from the gameplay [53].

Road safety and green mobility are two major concerns for making transportation efficient and convenient for road users. The increase of vehicles and transportation needs of users have created problems such as traffic congestion, accidents and environmental pollution in major cities [55] [56] and these problems remain as hindrance for green and safe mobility of users. While inspecting the issues for the cause of on-road hazards, driver behaviour has the maximum contribution [57] [58]. Driver behaviour not only accounts to fatalities but also in fuel consumption and environmental pollution [59]. As the driving controls (managing speed, braking and gear change) depend on the driver, it causes high fuel consumption when these parameters are not used properly [60].The fuel used during the trip is associated with the emission of pollutant gases, and the driving style of driver determines the vehicle's quality in the longer run [61][62]. The methods like eco-driving [63] and eco-routing [64] are deployed for saving fuel and improvising driving style. Driver behaviour assessment through in-car models are getting more prevalent, and in-car driver support models have a direct association with drivers. These models are used to assist drivers in various tasks involving contextual, behavioural and for the betterment of performance as well. The driver support systems have more tendency to eliminate the on-road impacts and fatalities caused due to driver behaviour [65]. For, the purpose of estimating driver performance, the approaches involving the extraction of vehicle signals through CAN (Controller Area Network), or smartphone sensors are used [66] [67] and later these vehicle signals are associated with driver performance. The car manufacturers have taken smart driving initiatives, which enables driver to track and share driving behaviour with peers. There brings better awareness in drivers about their driving. Carwings of Nissan is one such application, which represents the fuel consumption status, money spent vs. buying gas and a comparison of performance with peers [68]. Car2Go, a car-sharing service promotes gamification by grading drivers for environment-friendly driving habits based on acceleration and braking behaviours [69]. From the state-of-the-art analysis, there are numerous approaches, which are addressing the issue of road safety factors from the viewpoint of driver behaviour. By providing necessary knowledge about the driving pattern, a training aspect can be induced in drivers and eventually training of drivers can improve green driving behaviour [70]. The use of gamification process for improvising driver behaviour can benefit the road users in rectifying harsh manoeuvres, understanding performance outcomes and maintaining optimal driving behaviour consistently. Taking all these aspects in consideration, will discuss the vehicle signal processing and real-time gamification models for enhancing the driver behaviour.

The research and experimentation mentioned in the references are either of simulation or driver specific score for himself or for insurance company. Few of the experiments are performed as demonstration tests in specific environment but not having any scope for day-to-day use by the vehicle drivers. The objective of this thesis is to bridge the gap of serious games experimentation in transportation sector and its real-time use in daily life. Framework uncovers experimented methodologies including evaluation of driver performance, Automation of those evaluations by reducing an interaction of vehicle drivers and plug-ins availability for the new games by leveraging the framework. Framework has features like Comparative scores of the drivers driving on the same routes, their historical performance of rides and Application dashboard with details of winner, awards and its graphical data representation. These features would bring entertainment, knowledge and awareness under the same hood. The mention features comparison of drivers' score is dependent of many factors, which includes location, time, distance of travel, exact route of travel, time required to complete the travel and how many users are in the same competition. When these factors are satisfied then only Green driving or safe driving criteria's can be applied for the comparison of their scores. To make this possible framework has server services which keeps tract of competition routes, time slots of competitions, routes of competition, users subscriptions for the competitions and their temporary scores on specific intervals. Input for the serious game is evaluation of the driver performance, so evaluation should be correct and thesis provides detail of scenarios, concerns and findings. There are still many barriers which includes comparison of driver performance of different car models, comparing smart phone based evaluation with CAN bus based evaluation, Automatic start and stop of evaluation with minimal or no configurations by the vehicle driver.

3. Assumptions and Scope

The Evaluators implemented are having few assumptions about the safety, Green driving and their trade-offs against each other in certain conditions. In practical demonstrations, vehicle partners were more interested in safe driving over green driving. Although one algorithm can evaluate the safety and green driving at the same time, I had kept split of 40% green and 60% safe drive evaluation in the car bundles. So, if user get 70/100 in green driving and 80/100 in safe driving then user gets 28 + 48= 76/100 in overall. This scoring split is just a preference I had chosen on the day of demonstration, and in same way, when user creates a new competition, this distribution of safety against green driving would be the preference of the competition designer. The User can get this details in competition description and can decide whether to subscribe for this competition or can find alternative one according to this daily route and competition criteria he/she wish to get evaluated in the drive.

Few environmental factors like road condition, rainy season and snowy roads are outside the coverage of this thesis. Few gamifications developed by lab team using this framework and few user studies have got conducted on those, but discussion of user test is also out of coverage of this thesis.

There are 3 smartphone applications have got used in this framework. 1) In-Application evaluator 2) SG-CB app 3) Automatic Staged Competition Application. The SG-CB Application is the only one application which is mandatory to be used by the vehicle driver. This Application does not serve any purpose when driver is driving, and it required to be used when driver is not driving. So this application won’t cause in distraction to the driver. Another application is Automatic Staged Competition Application, which is used to create competitions and subscribe to competitions by other users. So, this is also used very often and does not required to be used when driving. There is In-Application evaluator which in-turn has a relation with driving because smartphone is required to be mounted in the front desk of the car, with application instance running. When this application runs, values from phone sensors gets processed and the evaluation of the driver happens continuously and results sent to the server on regular interval. Considering the fact that user does not required to interact with the application after he start the application, distraction is almost negligible.

4. Architecture

The major tasks of this approach involves the evaluation of harsh patterns from the acquired vehicle signals (Speed, RPM, acceleration, etc.,), understanding the driver behaviour and to enhance the better driving traits. The vehicle comprises of an OSGi environment [7], where the evaluators and signal receivers are deployed in the OSGi environment (knopflerfish) as bundles (developed in java, JAR bundles). Vehicle Signals are transmitted over to VDP consumer bundle using VDP APIs in the OSGi framework and from which the signals are assessed by driver performance assessment module (comprises of the three evaluators) and then the evaluation scores are sent to the cloud server using RESTful API by HTTP request-response. The data from the server is accessed using a smartphone application called SG-CB (Serious games and community building) for Graphical representation, statistical reports, and for Serious Games development.

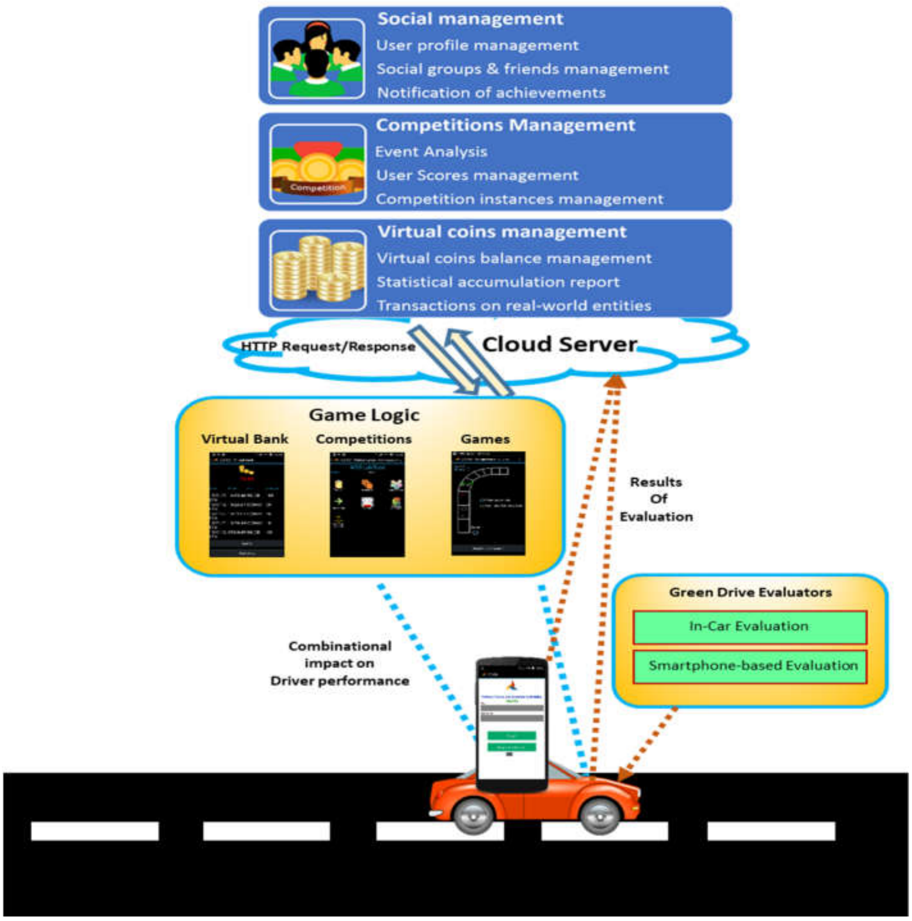


Figure 1: Overview of Framework Architecture and Communication

As fig. 1 and fig. 2 shows, the car has 2 evaluators, In-car evaluation and smartphone-based evaluation also called as In-Application evaluation. The results are getting sent to cloud server and few gamifications are getting reflected according to the scores of the driver. The Game logic is a gamification, which have developed by university of Genova, team members and also it is possible for future research to use this platform and create new games.

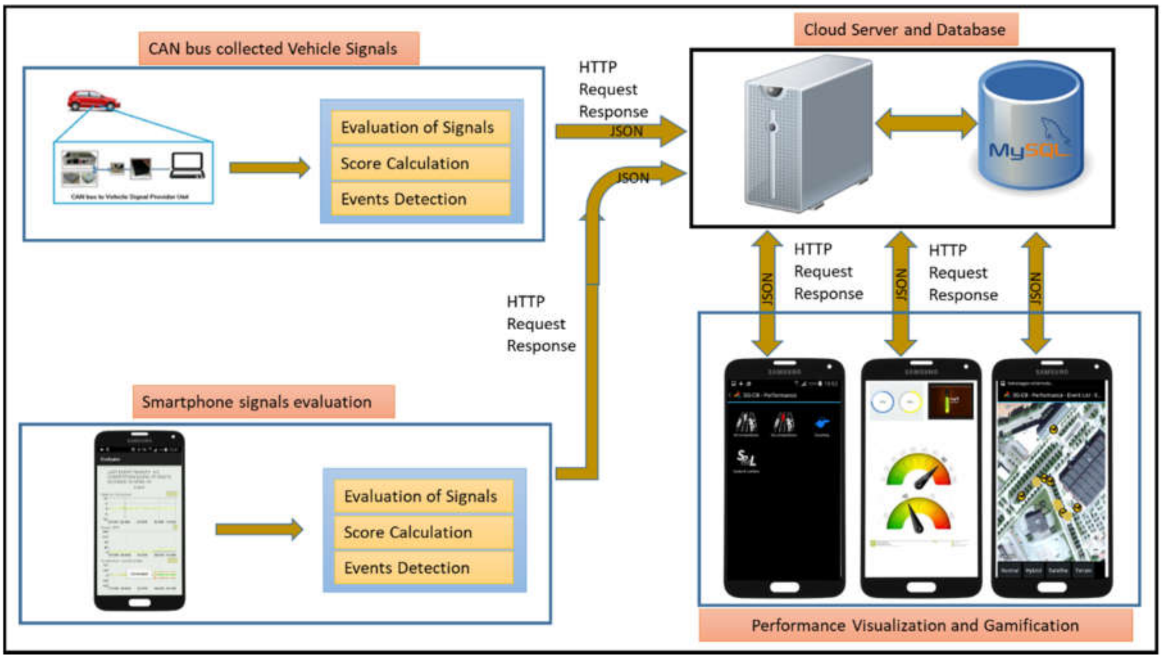


Figure 2: Evaluators, cloud server and Visual elements

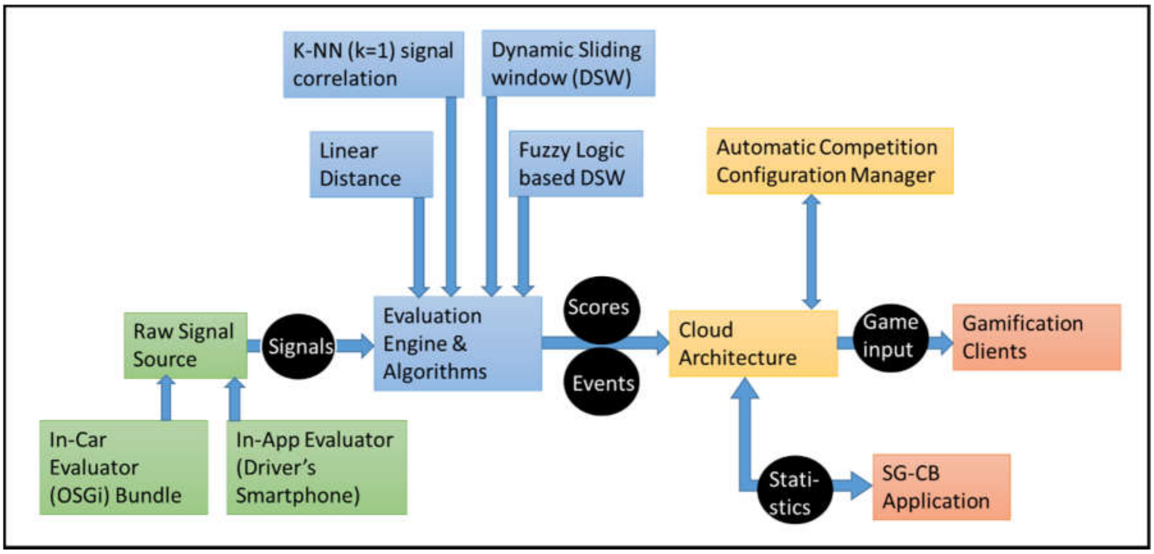


Figure 3: Data flow from Evaluation to Visualization and Gamification

As explained in fig. 3, the client modules are Evaluators, SG-SB application, Automatic competition configuration Application and Games. The server is responsible for managing the communication using HTTP request response calls. The cloud has Apache Tomcat server running with RESTful API implementation and MySQL database. The Evaluation, Games and SG-CB application communicate with server using HTTP request response requests. The server is having different modules to serve different purposes.

In-car evaluator uses CAN bus signals from the car and using algorithms process these signals to evaluate user score, detects harsh events. The In-Application evaluator uses mobile sensors like Gyroscope, Accelerometer and GPS location for evaluating the vehicle driver. The In-car evaluator uses different algorithms to analyse the data and evaluate the user score in real time. These algorithms will be explained in next session. The In-car evaluator and In-Application evaluators communicate the scores, events, times, GPS location with Longitude and latitude and user information to the server using HTTP request (refer fig. 4). The server responds with insertion confirmation.

The Automatic Competition Configuration Manager is responsible to support automatic configuration of evaluation and setting up competition environment for the user. This provides ease of user for vehicle drivers for competing in Green Driver competitions just by subscribing a competition and having evaluator turned on for the evaluation. More about this module will be explained in session 6.

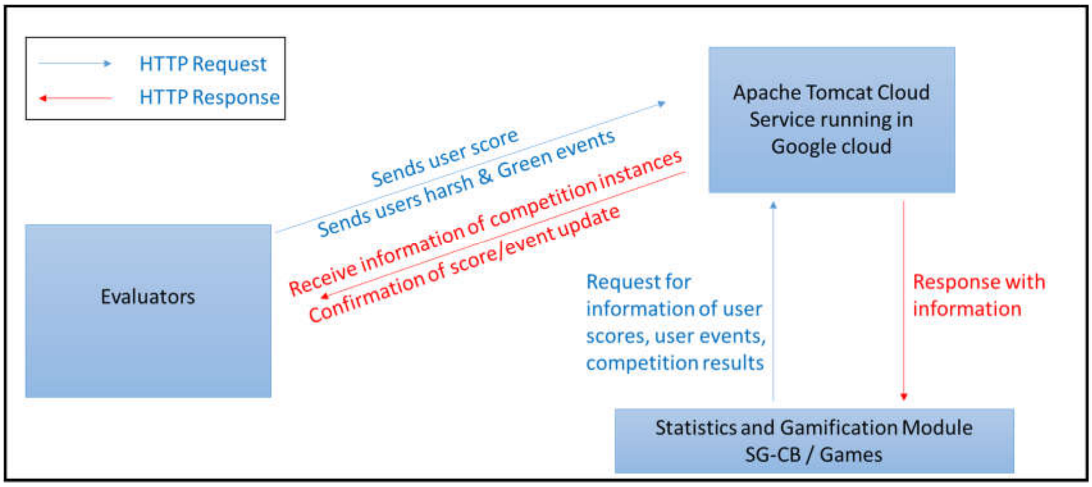


Figure 4: HTTP request-response based RESTful APIs

The results of users send to server by evaluators are accessible to SG-SB application for the presentation to the user about his/her performance, which includes performance in particular competition, historical performance over the time and performance comparison with other users. Users also can check their harsh manoeuvres on the road on google map and also can check their prize related information and virtual coins which they achieved in case of winning the competition.

The partial scores of the user on regular interval are accessible on the server for the implementation of Games. The Gamification module is responsible for providing the information of user score on regular time interval. This exposes a new way of segregation in serious games as Game designer can develop a game without being aware of exact methodology of the evaluation.

4.1 Social Gaming prototype scenario

The social gaming scenario consists of various competitions (drive around a location, for example: a city) comprising a peer evaluation, where the competition involves the participation of multiple users and each user in the competition will be evaluated and granted a score out of 100 (scores will be calculated based on the results of the evaluators used). The competition user holding a highest score will be declared as the winner of competition and will be awarded with the virtual coins. The users can get virtual coins at any time by exhibiting safe and green driving behaviour, as virtual coins are continuous evaluation of driver performance independent of peers, routes and competitions.

4.2 Competitions:

In competitions approach, the user can take part in a time framed competition (a competition might last from 10 – 15 minutes depending on the locality) by subscribing for the open competitions (the competitions are opened on timely basis) and exhibit better driving behaviour to surpass the peers in competition. The term competition in this occasion can be defined as a geographical location associated with any road network in a city. In a competition, users are evaluated for their performance by the two green drive evaluators on the basis of vehicle signals (acceleration, brake, engine RPM, and speed) and the smartphone signals (GPS, accelerometer, and gyroscope). While, on the go the users can check the scores of their subscribed competitions and also can look for the fluctuations in scores based on the performance in competition. On completion of a competition, users can check their detailed report of scores, rankings, performances and comparison with peers. The competition strategy, grant scores and generate the rankings based on the comparison of user performance with the performance of peers, so this aspect comprises of impact in evaluation from various users in the competition. Some virtual coins are also granted for scores secured in the competitions. Whilst, analysing the performance in competition, the users are also assessed on harsh driving events such as harsh braking, high acceleration and high levels of engine RPM. At the end of competition, the tracked harsh events are displayed on Google maps along with the harshness level (high or average) and this methodology would serve the purpose of training drivers by making aware of the harsh patterns exhibited during the drive.

4.3 SG-CB (Serious Games & Community Building) Application

HMI has been designed to have a very little impact on the driver, while allowing third parties (e.g., a passenger) to assess to information in real-time. As shown in fig. 5, few performance visualization and gamification interfaces are provided in this application. The historical data of performance and comparisons with other users are available for user. There is separate session for the Performance Visualization and Gamification to discuss more about this in details.

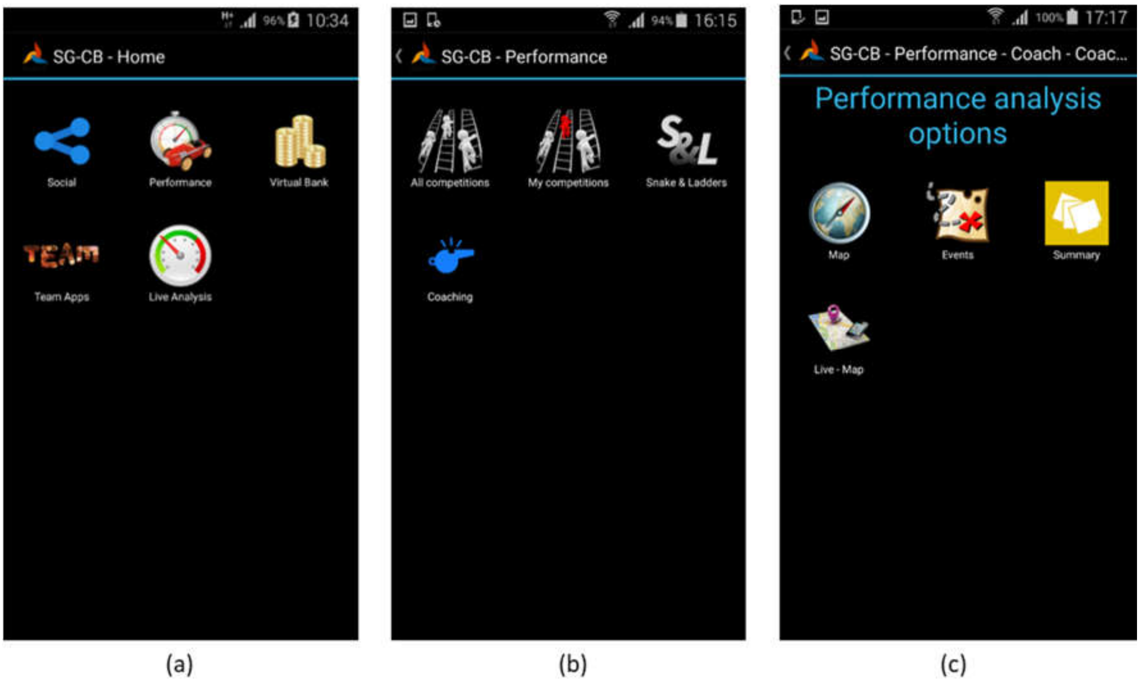


Figure 5: Serious Games and Community Building Application introduction

4.4 Virtual Coins

The user gains virtual coins (rewards granted based on the performance) for optimal driving. The virtual coins are accumulated in the virtual bank and they can be used on real-world entities such as purchasing bus tickets, reservation of parking space and etc. Fig. 6 shows snapshot of user's virtual coins and using it for purchase of bus tickets. This is most common incentives used in TEAM project, research team in my lab had come up with this concept and for all application linked with the framework, and Virtual coins are supported as one of the medium of incentives.

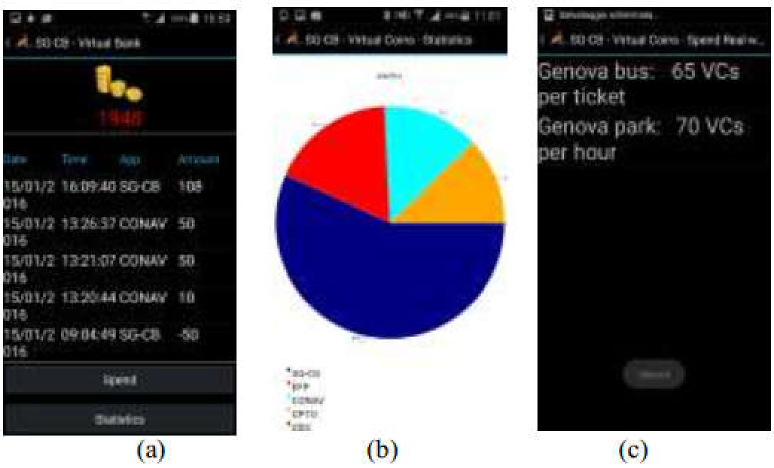


Figure 6: SG-SB showing earned virtual coins by user and usage

5. Vehicle Performance Evaluation

The gamification aspect is based on green drive performance of driver by assessment of various vehicle signals (acceleration, brake, speed and RPM). The vehicle signals are extracted from CAN bus, and they are sent to an in-car evaluator module (units for signal processing and performance evaluation are deployed as bundles in OSGi platform [71]). In the OSGi environment, the bundles interprets signal values from the CAN Bus and transfers it to VDP (Vehicle Data Provider) bundle in OSGi environment, and subsequently sends the signals to different evaluator applications which uses VPC (Vehicle Data consumer) service, which also runs in OSGi environment and have subscribed for signals. Due to this approach of pipelining, the addition of new evaluator would not require any code changes and configuration change can allow access to that.

The Green Driving and Safe Driving are measurable features of better driving practices. The User driving performance can be determined using vehicle signals. This section will provide explanation about how vehicle data is collected from vehicle, how raw signals are processed to get user driving performance knowledge and how process can be standardized to use it for different vehicle models. Evaluation activity is divided in to two phases, and mentioned in this section as pre-Test and post-Test phase. The pre-Test phase / Data Analysis covers the activities and research methodologies when the actual site tests were not available and models used to run on data sets given my different car models. The Run-time phase/ Run time Evaluation covers the real-time evaluation of the driver when OSGi environment running inside a car and real-time values of signals gets analysed to evaluate a driver performance.

Pre-Test Phase / Data Analysis:

Activity started with the collection of the raw signals data from the Car, by installing log jars in to OSGi car environment. OSGi Jar Bundle, created log files for different car models for 20 minute long car test rides. This different car models data became available in log files. These acquired signal samples from FIAT, BWM and Mercedes Benz analysed to evaluate a vehicle driver performance.

We asked FIAT, BMW and Mercedes Benz car drivers to drive with different patterns which includes: Safe drive, Green drive, Harsh and unsafe drive. The pattern of driving was already known for each drive, and samples log collected from the car for each of those drives. The harsh manoeuvres includes high RPM, harsh brakes, harsh accelerations and brake with steering wheel rotation. Collected Samples analysed in python to understand nature of different signals. It is importance to analyse the data when vehicle is moving, so, most of the observations presented in this whole section are filtered with for speed >0. These drives has got conducted in training route which has highway equivalent traffic conditions. So described graphs in this section are depicting highway drive collected signals.

This research focus on practical way of evaluating driver performance and its gamification. The framework would allow evaluation developer to plugin new evaluators to the framework and game designers to use this evaluators scores to use as an input for their games. Harsh or rash instances are fraction of single percent of whole driving, so, evaluation need to be penalty based. In the real time competition, whenever driver apply any harsh pattern, Algorithm detects this moves and assign a Penalty, for this pattern. This penalty will inversely affect this competition score. If Harshness of driving is significantly high, and driver get high penalty, then driver need to be notified about this behaviour with the details about date, time, harness pattern and location where this harsh behaviour is observed.

Designed and implemented algorithms for estimating a driver performance are deployed on OSGi environment as JAR bundles. Evaluation patterns provide more scope for understanding driver performance on individual samples and accumulated event windows. The extracted vehicle signals are mapped and processed for understanding the driving behavior; harsh patterns from the signals are spotted and penalized. Harsh patterns comprise rapid brakes, frequent high acceleration, and the combination of steering wheel angle and brakes

5.1 Vehicle Data Analysis:

This section provides vehicle signals analysed using Jupyter notebook in Python. As the graphs explain, there are many different signals from the vehicle. By looking at the graphs, it is possible to get an idea of the normal range of every signal. Signal analysis have got performed in python, for understanding the behaviour of vehicle signals on different manoeuvres by the vehicle driver. To better evaluation the signals where speed is 0 are removed, that is vehicle is parked, or waiting on the signal. These analysis gives information of maximum possible signal values as well as average and standard deviations in their values.

The collected signal sample sets were used to perform some data analysis to understand the relationship between car signal and their relation with driver’s manoeuvres. I was knowing in prior about the driver manoeuvres, as these rides were designed to be harsh and smooth, in advance. So, the known behaviour and the signal values were required to be mapped and crosschecked against each other. Although the information of event is known, the event like brake actually takes multiple samples and few of them can be a good braking subset and few values with harsh values. So, to analyse the harshness knowing the natural pattern of the signals is recommended. The Data analysis phase has 3 sample data sets and fig. 7, fig. 8 and fig. 9 shows BMW, FIAT and Mercedes-Benz car signals snapshot respectively. These graphs gives an idea about the nature of signal, and few correlation graphs provide more information about signal relation with another signals.

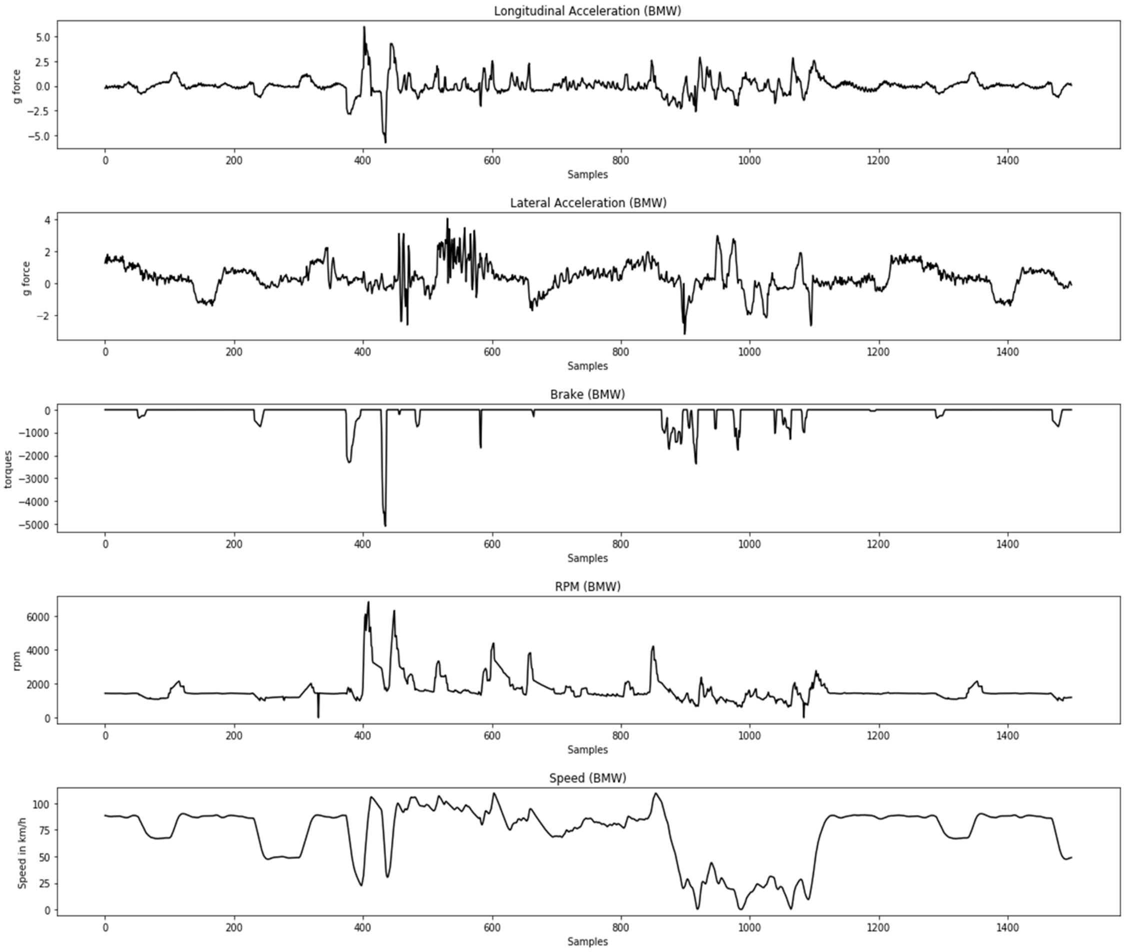


Figure 7: BMW Signals from CAN bus collected log

BMW Nissan snapshot represent few samples of the data set, few observation about BMW signal samples :

1. Longitudinal Acceleration Range :

   Approximately -5 yo +5 gravity force m/s2.

   As the whole data set -6 yo +5.5

2. Lateral Accelearation Range :

   Approximately -2 to +4.

   Approximately -3.8to +5.

3. Brake values range :
   Approximately : 0 to -5000
   As the whole data set 0 to -6100
4. RPM range :
   Approximately : 0 to 6500
   As the whole data set 0 to 7100

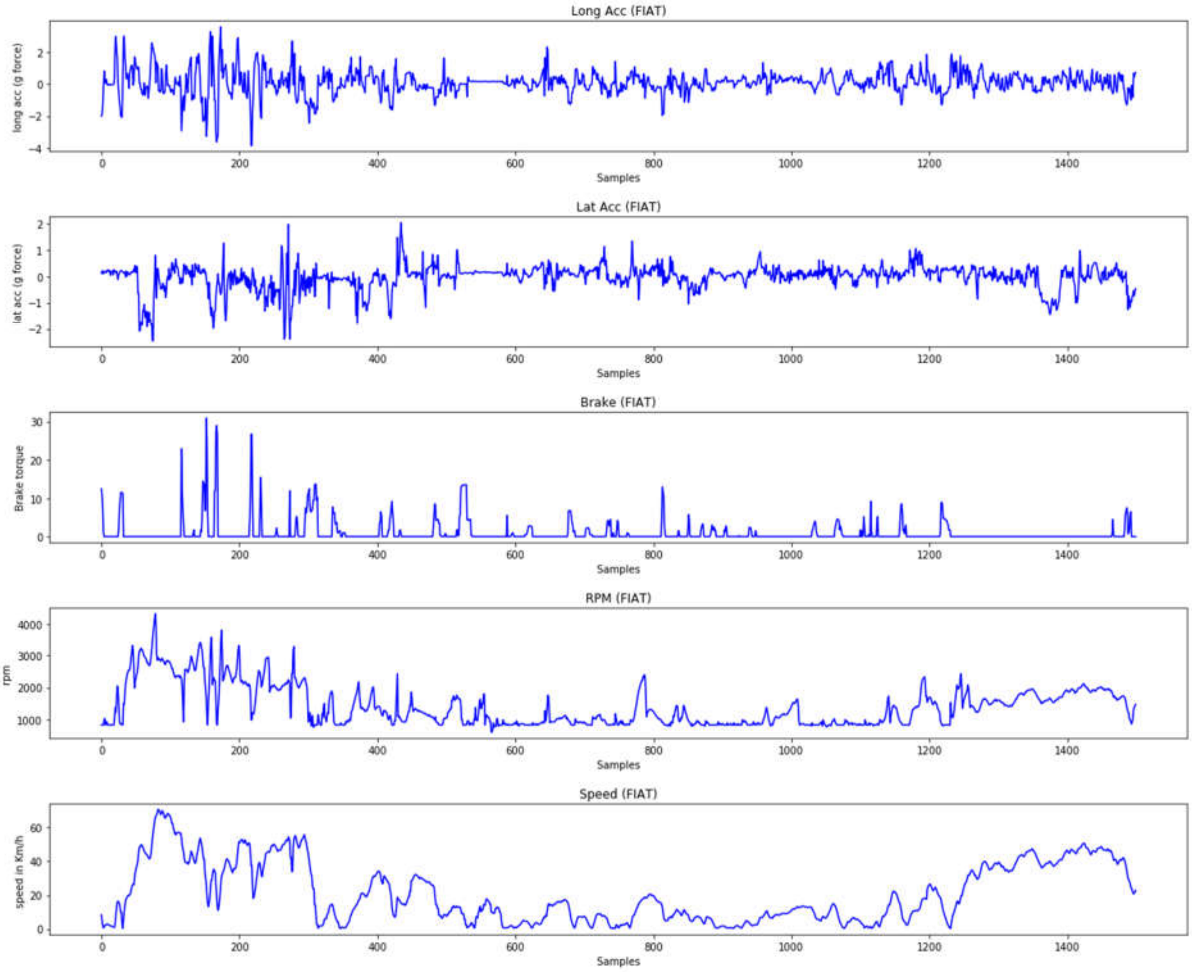


Figure 8: FIAT car Signals from CAN bus collected log

FIAT 500 car snapshot represent few samples of the data set, few observation about FIAT 500 signal samples:

1. Longitudinal Acceleration Range :
   Approximately -4 yo +2 gravity force m/s2.
   As the whole data set -4.2 yo +3.5
2. Lateral Accelearation Range :
   Approximately -2 to +2.
   Approximately -2.2 to 2.3.
3. Brake values range :
   Approximately : 0 to 30
   As the whole data set 0 to 60
4. RPM range :

Approximately : 0 to 4500
As the whole data set 0 to 5200

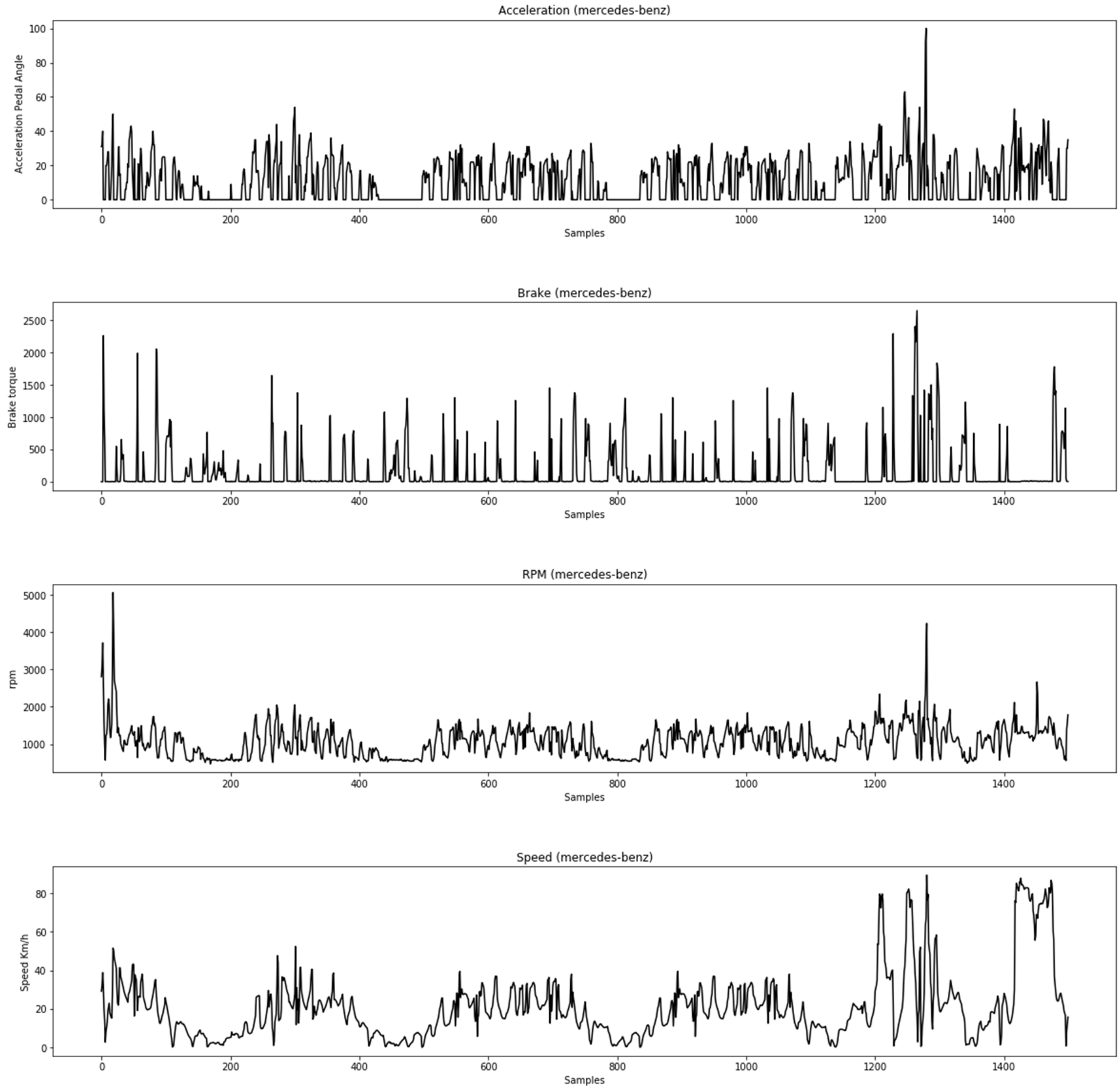


Figure 9: Mercedes-Benz car Signals from CAN bus collected log

Mercedes Benz car snapshot represent few samples of the data set, few observation about Mercedes Benz signal samples:

1. Acceleration Range :
   0 to 100 gravity force m/s2.
2. Brake values range :
   Approximately : 0 to 2500
   As the whole data set 0 to 4200
3. RPM range :
   Approximately : 0 to 5000
   As the whole data set 0 to 5200

5.1.1. Basis of Evaluation:

The driver evaluation is based on 9 signals: Acceleration, Longitudinal Acceleration, Latitudinal Acceleration, Brake, Speed, RPM, Steering wheel angle, steering wheel rotation speed, and GPS latitude and longitude values. The pattern of braking signal itself provide vital information of drivers driving pattern. Observation shows relation between Speed and Brake harsh moves, as if brake is applied harshly when vehicle speed is low, it will not end up in unsafe condition but risk will be considered higher as speed is higher. The so, various dimensions come in to picture to evaluate penalty. Another important factor is duration of brake or number of multiple brakes in specific period, which affect the scores of driver.

5.1.2 Normalizations

As it can be observed from the fig. 10, fig. 11 and fig. 12 the brake, RPM, and acceleration values are different for different car models, and that rises a concern for the algorithm to mine the data correctly. The scaling the data with normalization or standardization were the options. As fig. 7 shows the BMW treat the Brake signal in negative number, whereas FIAT and Mercedes Benz car has positive high value for the brake. So, decision was to go with normalization and use the absolute values for the signals, which can resolve problem with negative values. Considering the magnitude value away from the 0 shows harsh event, the absolute value usage and normalization does not create a situation where loss of information can be possible. The following fig. 10, fig.11 and fig.12 shows the normalization of BMW, FIAT and Mercedes-Benz car signals respectively.

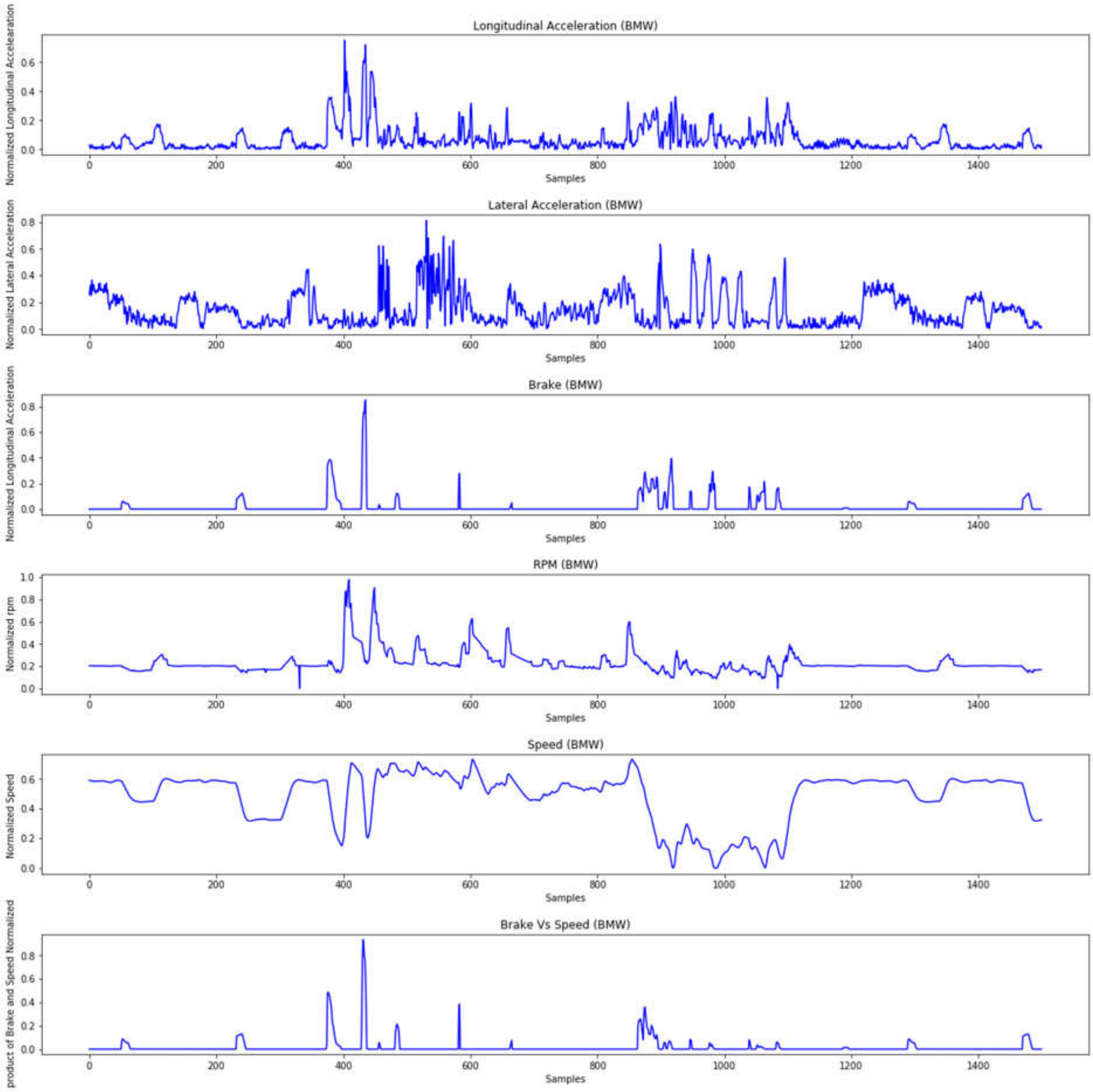


Figure 10: BMW car Normalization signals

The fig. 10 shows the normalized values for the BMW Nissan Car model signal. The BMW Nissan car had negative values for the brake ranging from 0 to -5000, now these values are in range of 0 to positive 1, and the nature of brake signal is unaltered. As well as, the Longitudinal Acceleration and Lateral Acceleration also have only positive values. As the magnitude of the value only show the harshness, converting these from negative to positive does not results in to loss of information. There is another 1 signal is introduced which is a Brake Vs speed signal. As brake value with low speed does not have a great impact on harshness, but brake value with high speed values results in to harsh brake event. So, this signal have added to visually understand such cases in the test ride. Having these values in a range of 0 and 1, gives a better chance of having 1 algorithm which can evaluate the vehicle driver performances on different car models.

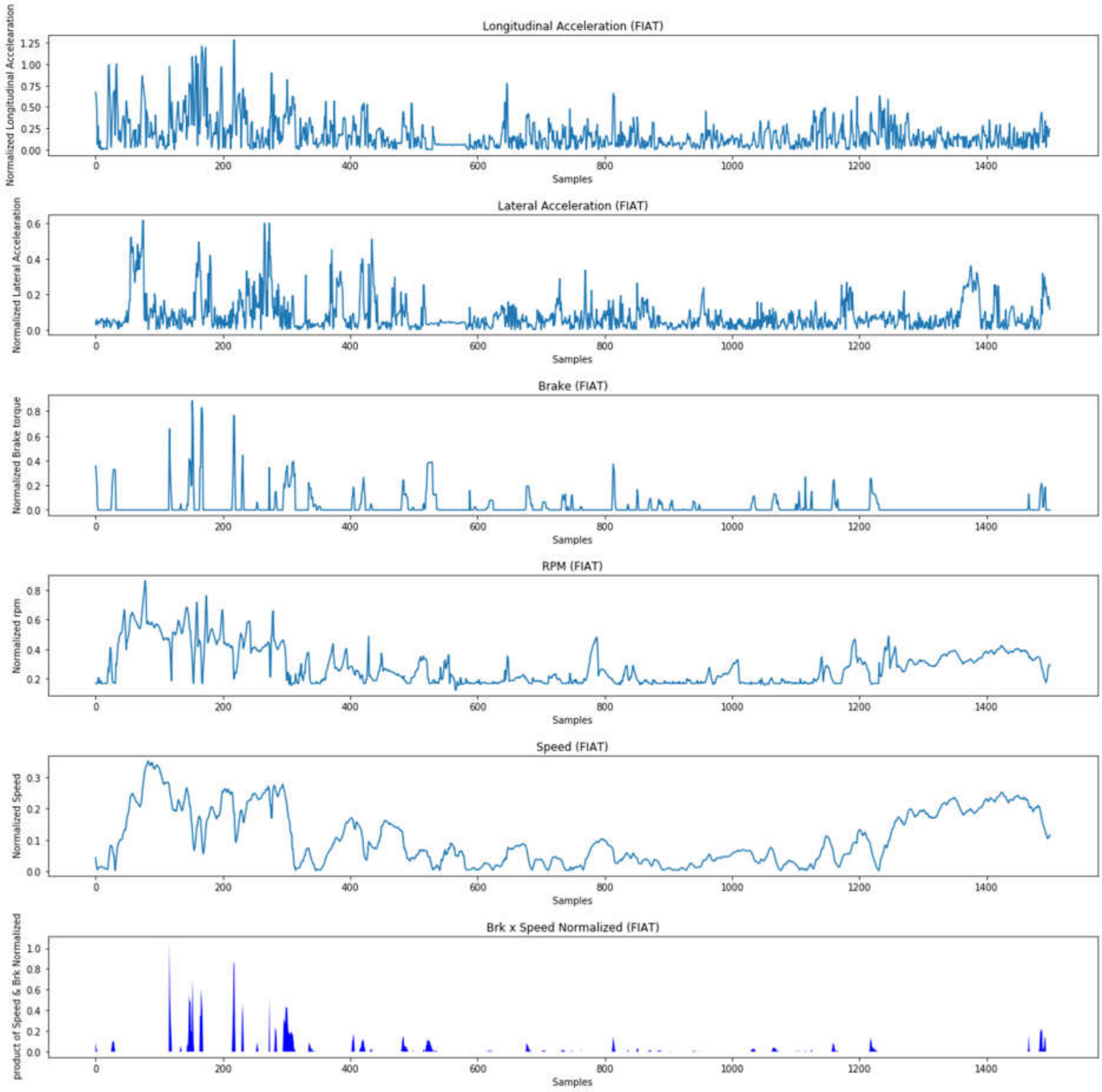


Figure 11: FIAT car Normalization signals

The fig. 11 shows the normalized values for the FIAT 500 car signals. The Longitudinal Acceleration and Lateral Acceleration values are not only in positive range. Same as per BMW, new signal Brake vs speed was introduced to present the harsh event graphically.

The fig. 12 shows the normalized values for Mercedes-benz s-class car signals. Although all the signals' values of Mercedes-benz are positive, only normalization was required to perform for achieving value range from 0 to 1.

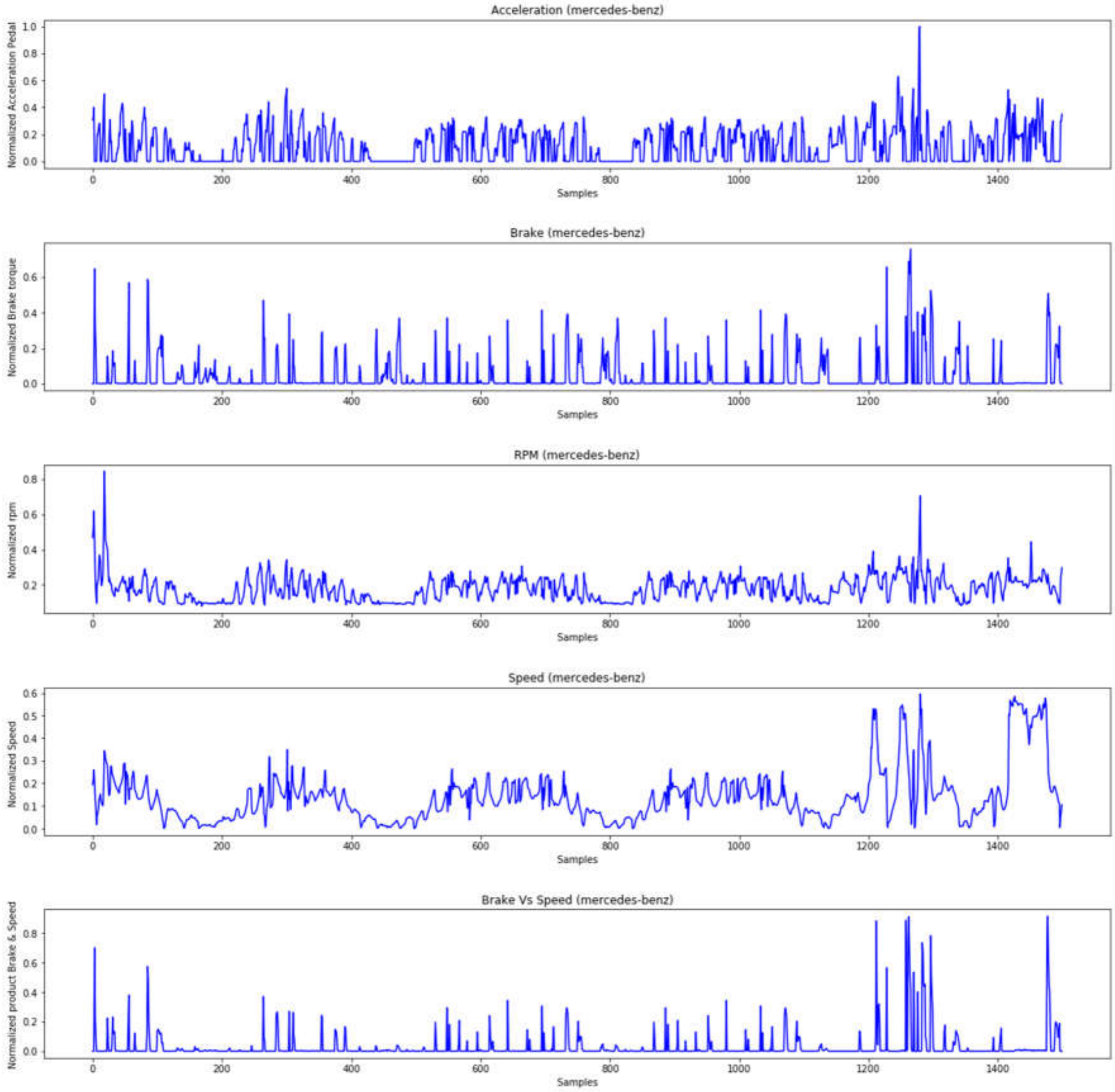


Figure 12: Mercedes-Benz car Normalization signals

5.1.3 Observations, Possible False conceptions and clarifications:

The normalization graphs of all the car can give an idea about the signal nature, but also create some false conception. For example, by observing Mercedes-Benzes signal for brake vs speed, it seems evident that the driver has applied lot of harsh brakes and he/she was aggressive on the road. But, unless until have a knowledge of the real optimal range of brake, it is not possible to conclude if behaviour was harsh or normal. To solve this problem, I have used average and standard deviations and implemented them in program with dynamic update. The value reflect whenever there is a new value for maximum, minimum, average of last n-samples and standard deviation in last n-samples.

5.2 Signal Correlations:

For better understanding of the relative changes in signals, I have correlated those signals. The Graphs below shows the correlations between those signals.

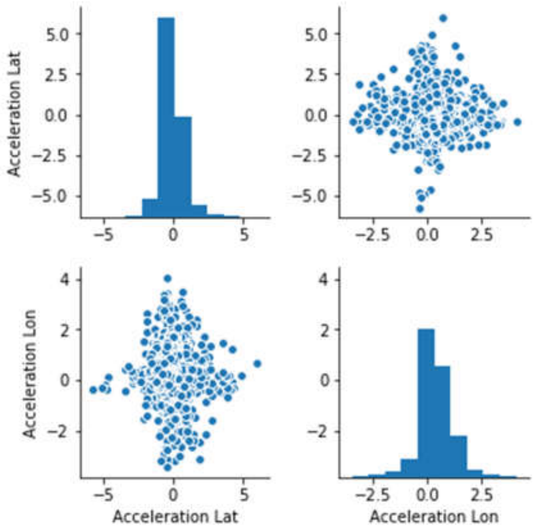


Figure 13: Correlation of Longitudinal (g-force m/s^2) and Lateral Acceleration (g-force m/s^2)

The fig. 13 shows the relation between lateral and longitudinal acceleration. It can be observed that, either of these value generally can deviate from 0, but both values deviating from 0 with high margin are relatively very less.

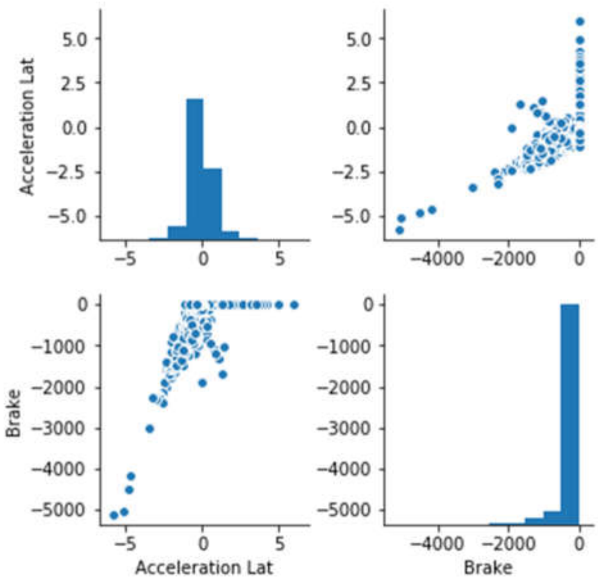


Figure 14: Correlation of Lateral Acceleration (g-force m/s²) of Brake torque (Newton Meter Nm)

Fig. 14 shows the relationship between the Brake and Lateral Acceleration. It can be observed that when value for brake is high, lateral acceleration value is deviating toward -5, and it means driver is preparing for the turn (specifically right turn or stopping for the parking).

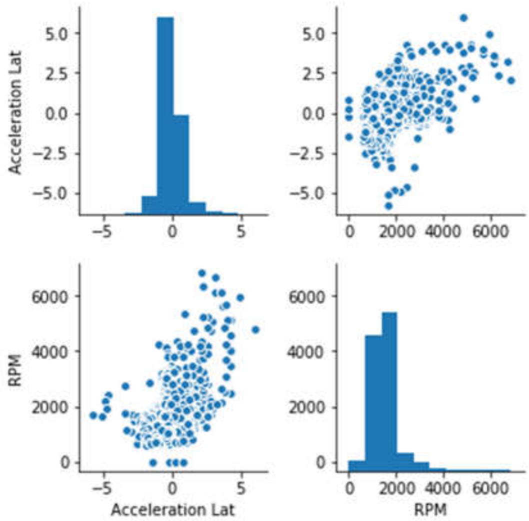


Figure 15: Correlation of Lateral Acceleration (g-force m/s²) and RPM

The fig. 15 shows the relationship between RPM and Lateral Acceleration, it can be observed that with high value of RPM, Lateral acceleration is deviating towards positive higher values, and it means driver is taking left turn and can infer that vehicle speed is high.

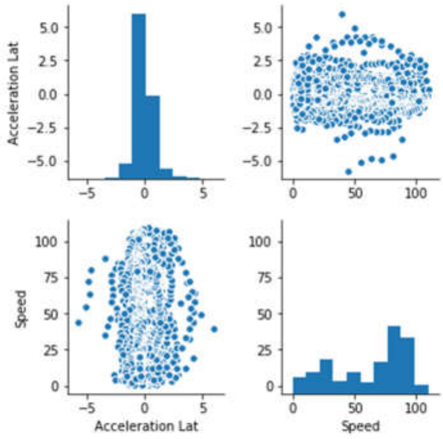


Figure 16: Correlation of Lateral Acceleration (g-force m/s²) and Speed (km/h)

The fig. 16 represent the relation of Speed signal to Lateral Acceleration and basically there is no relation between Lateral Acceleration and speed could be found in this snapshot, as with speed values all variations of lateral acceleration values spread approximately in same density.

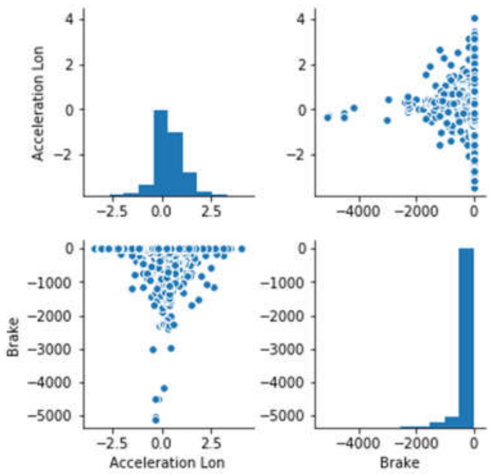


Figure 17: Correlation of Longitudinal Acceleration (g-force m/s²) and Brake torque (Newton Meter Nm)

As longitudinal acceleration fig. 17 represents the acceleration and deceleration movement of the car, graph depicts that the higher value of brake vehicle movement further or reverse is getting restricted.

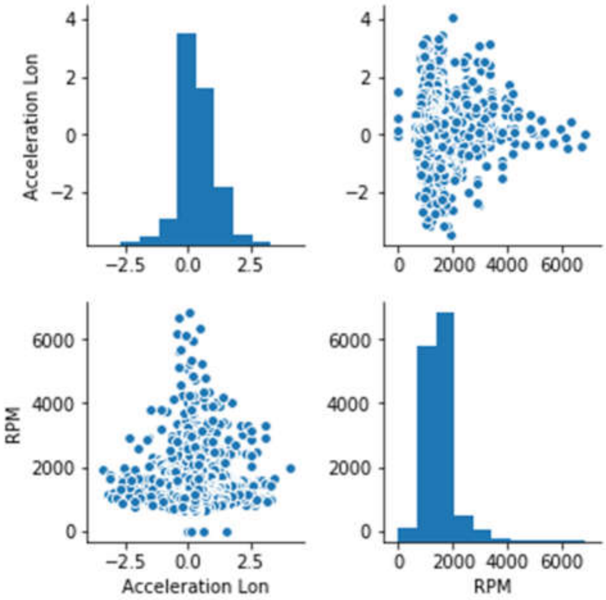


Figure 18: Correlation of Longitudinal Acceleration (g-force m/s²) and RPM

The fig. 18 represents the correlation between RPM and Longitudinal acceleration, and it can be observed that, with high RPM car has achieved smooth speed, whereas with low PRM vehicle speed has an ever-changing value unless speed is around 0.

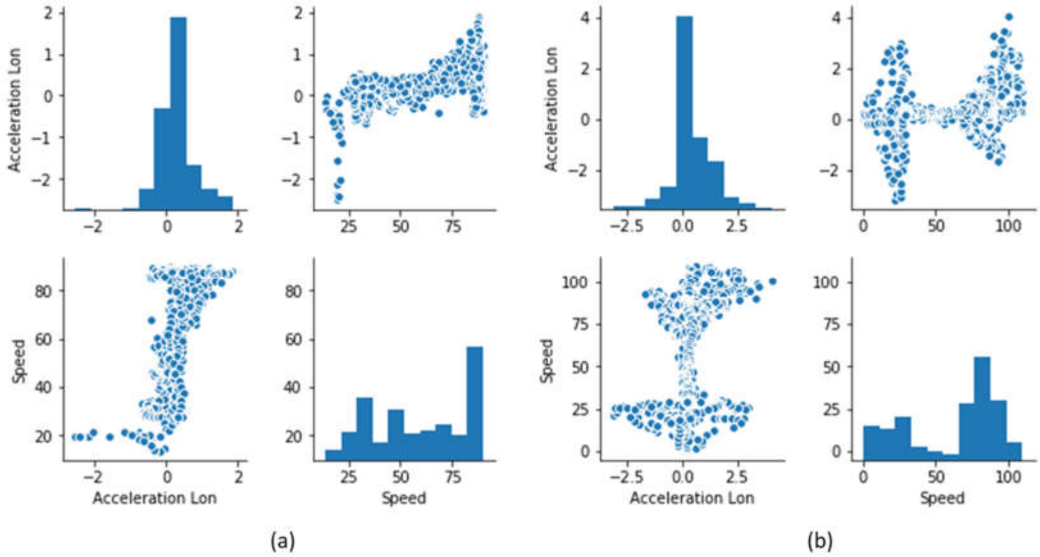


Figure 19: Correlation of Longitudinal Acceleration (g-force m/s²) and Speed (km/h)

Fig. 19(a) represent the relationship between Speed and Longitudinal acceleration. For better understanding between these 2 signals, 2 snapshots are represented. It can be observed in first fig. 19 (a) that, with high speed value, Acceleration longitudinal values deviate towards positive(acceleration), whereas with small speed values it deviate towards negative (deceleration). In fig. 19 (b) it can be observed that, the speed value around 50, has minimal longitudinal acceleration. So, there is some new information which can't be revealed only by relationship of signals.

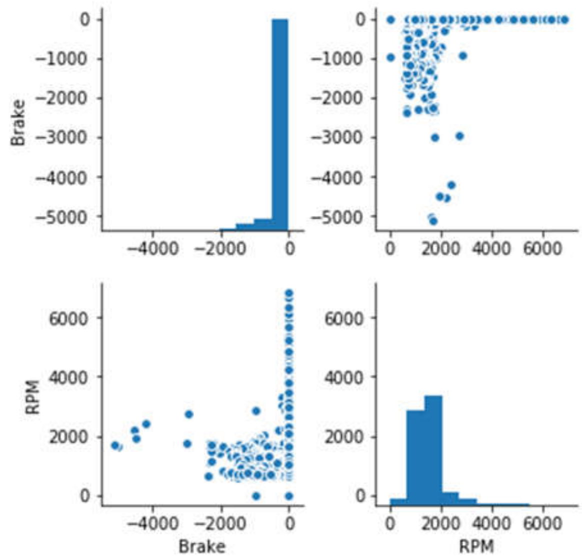


Figure 20: Correlation of Brake torque (Newton Meter Nm) and RPM

The fig. 20 shows the straight forward relationship between RPM and Brake. As brake goes higher vehicle goes to speed 0 so resulting low RPM. If brake is low it allows vehicle to speed up and RPM can be high according to vehicle speed, gear and road condition.

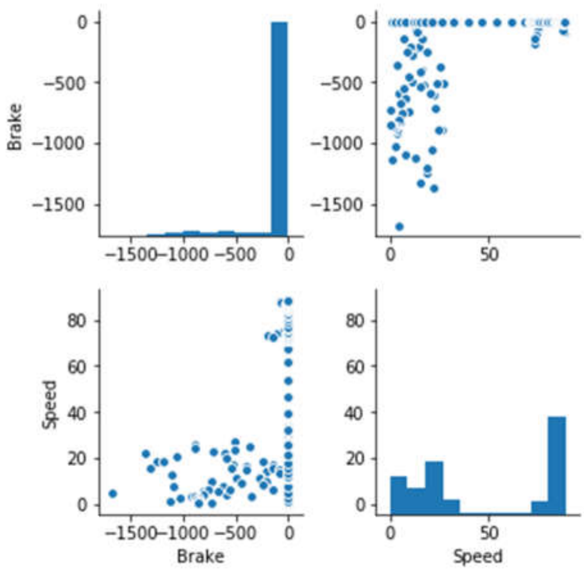


Figure 21: Correlation of Brake torque (Newton Meter Nm) and Speed (km/h)

The brake and speed relationship is depicted in a fig. 21. If brake value is high then speed value is expected to be low, whereas for having high speed, brake value should be low. Although these are snapshots of all signals, so it is possible to find few samples with high brake with high speed. This is because speed starts getting impacted for next subsequent samples. So if we plot brake and speed signals against time axis on x (as shown in fig. 10, 11, and 12), it can be observed that with high brake values vehicle speed gets changes inversely.

This information is helpful in understanding of brake, as with high speed even medium brake value can have high impact, and in normal cases this situation is rare. So, for penalizing user with reduction in score, the brake and speed relation plays important role.

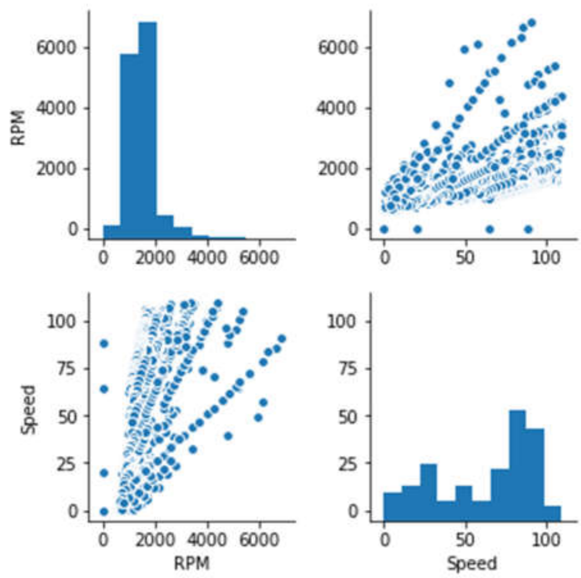


Figure 22: Correlation of RPM and Speed (km/h)

The fig. 22 shows the RPM and Speed relation, the diagonal lines actually represent a gears of vehicle, the RPM is expected to go higher with speed, but with low speed RPM going very high is not recommended. This gives a generic idea of operating RPM at particular speed level. Although this observation is not sufficient to find out if driving is green, but gives RPM information comparing with average RPM value of same speed range.

5.3 Penalty Evaluation

There are few more contributors in Penalty calculation which includes, high engine RPM, Harsh Acceleration, high Longitudinal Acceleration and High Latitudinal Acceleration.

In fig. 23, "Original + above thr = 500", This snapshot has been collected considering threshold is 500 for the Brake, and the above threshold events are marked in red whereas below threshold brake values are in blue. In "Penalty Event – PE", the binary value of event window, if it is in penalty is displayed. The "Number of PE in last 30 samples", shows the penalty calculation of last 30 samples. "Energy of PE – Area under the curve" shows the calculation of total penalty in the window which will be added together for final penalty calculation for the Brake signal. The "Even + intensity" shows the calculated penalty value in specific penalty window. It can be observed that around 380 to 430 samples, brake values were harsh with high speed, which drastically has reduced speed from 90km/h around to 40km/h. Accordingly its penalty calculation is showing number around 0.9 which is in fact very high penalty, and thus score of the user will get affected inversely. There are also few more instances of brake with some moderately harsh values and thus they are not having high penalty.

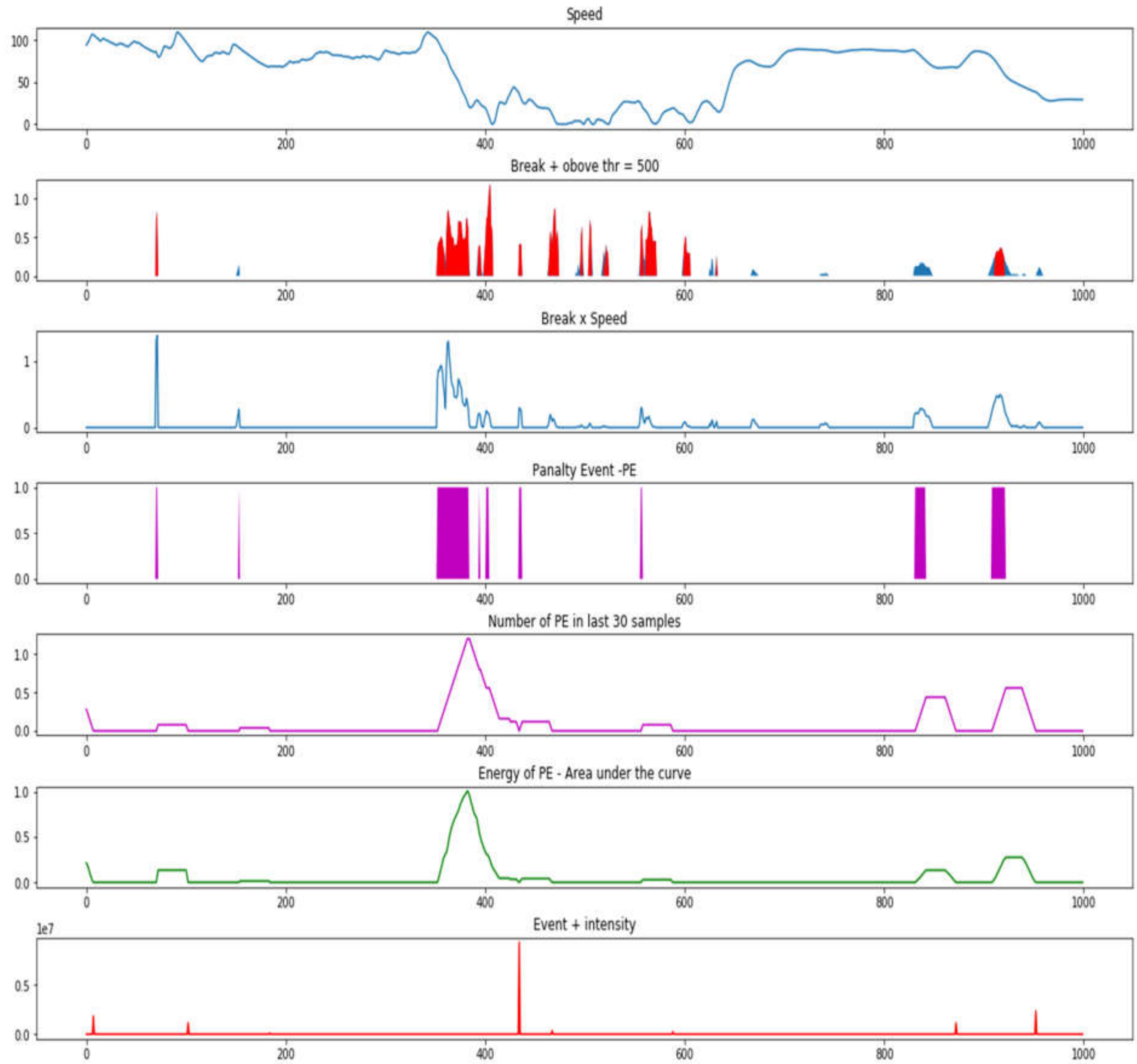


Figure 23: Brake Penalty calculation against speed with sliding window

In fig. 24, figure represent another case of brake, the “Original + above thr = 500”, considering threshold is 500 for the Brake, and the above threshold events are marked in red whereas below threshold brake values are in blue. In “Penalty Event – PE”, the binary value of event window, if it is in penalty is displayed. The “Number of PE in last 30 samples”, shows the penalty calculation of last 30 samples. “Energy of PE – Area under the curve” shows the calculation of total penalty in the window which will be added together for final penalty calculation for the Brake signal. The “Even + intensity” shows the calculated penalty value in specific penalty window. It can be observed that around 120, 270, 780 920, brake values were harsh with high speed, which drastically has reduced speed from 90km/h around to 40km/h. Accordingly its penalty calculation is showing number around 0.8 & 0.9 which is in fact very high penalty, and thus score of the user will get affected inversely. There are also few more instances of brake with some moderately harsh values and thus they are not having high penalty. Compared to last case, this driving behaviour is observed to be harsh.

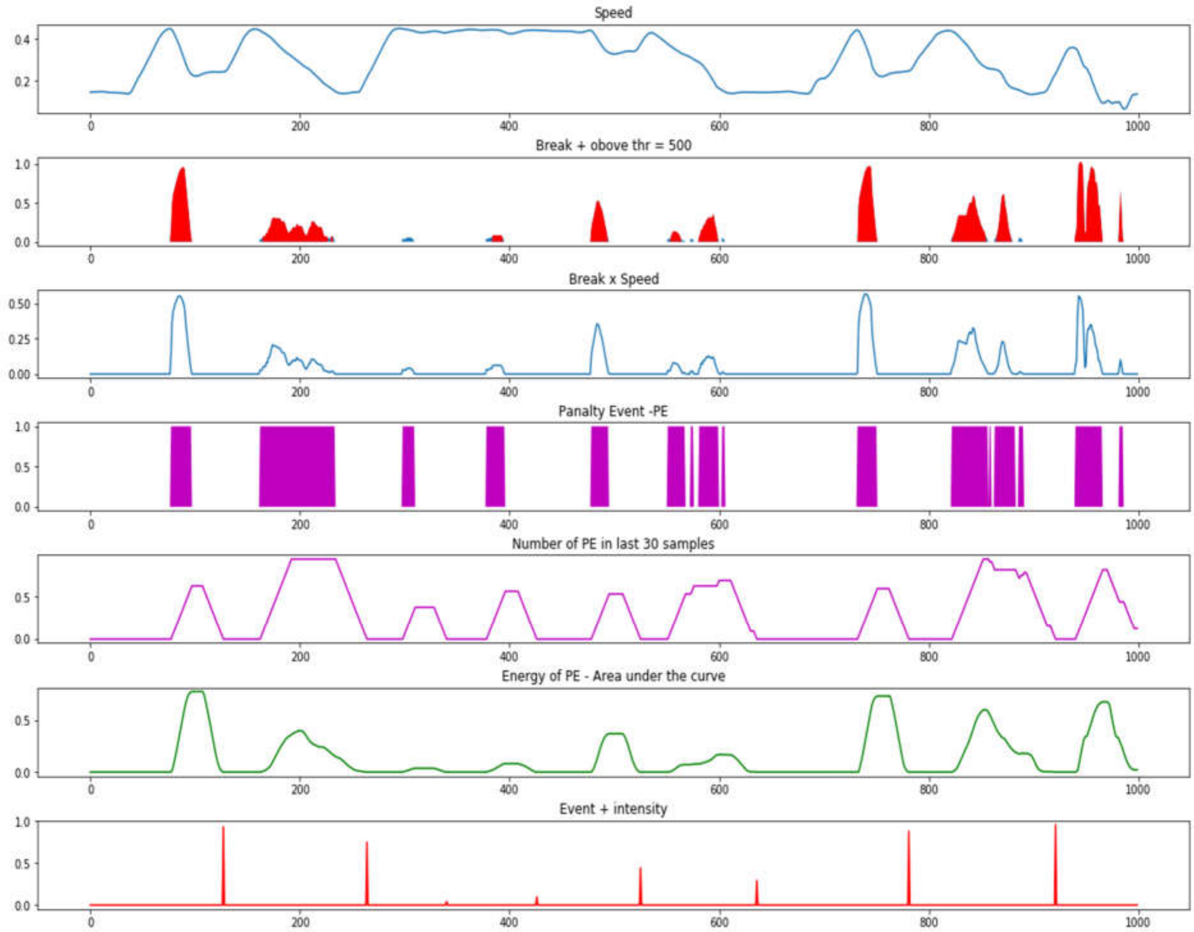


Figure 24: Brake evaluation against speed with sliding window and normalization for BMW Car

In fig. 25, figure represent another addition in case of brake with slope of change in speed as a new observation, The "Event- intensity" is already known as per fig. 24, then actual speed and normalized brake and speed values can be observed. The change in speed when brake is applied is calculated for finding of speed drop. The degree of speed drop would define the harshness of brake. Finally, this new calculated value has got used to recalculate the brake penalty.

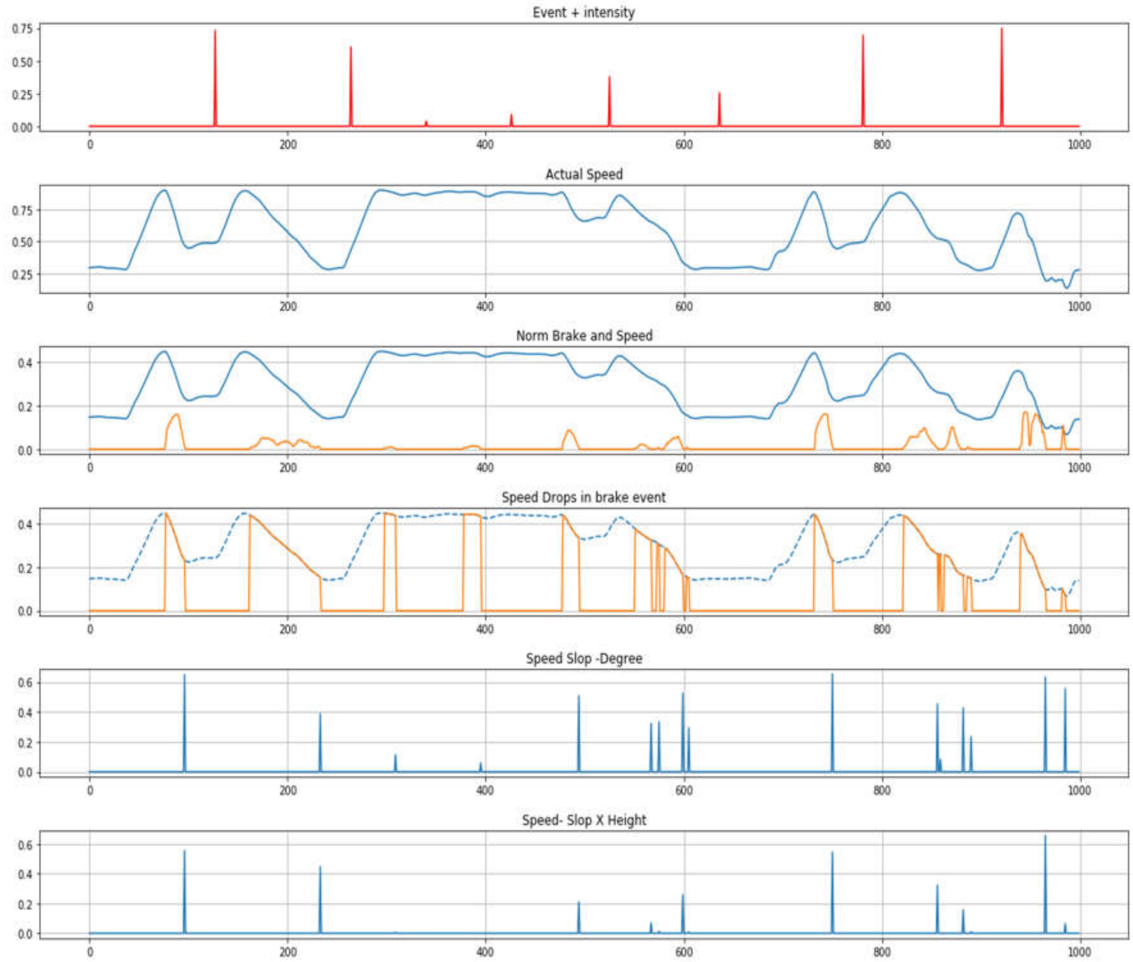


Figure 25: Slope of speed change calculation for better evaluation of Brake

In fig. 26, represent the penalty calculation of the case of High RPM and low RPM that expected. The RPM has a relationship with speed signal and with different speed values, RPM can have varying values for optimal range. Fig. 26 shows the possible samples which are high in value and calculate the area under the curve and energy of the penalty as a final penalty for that event.

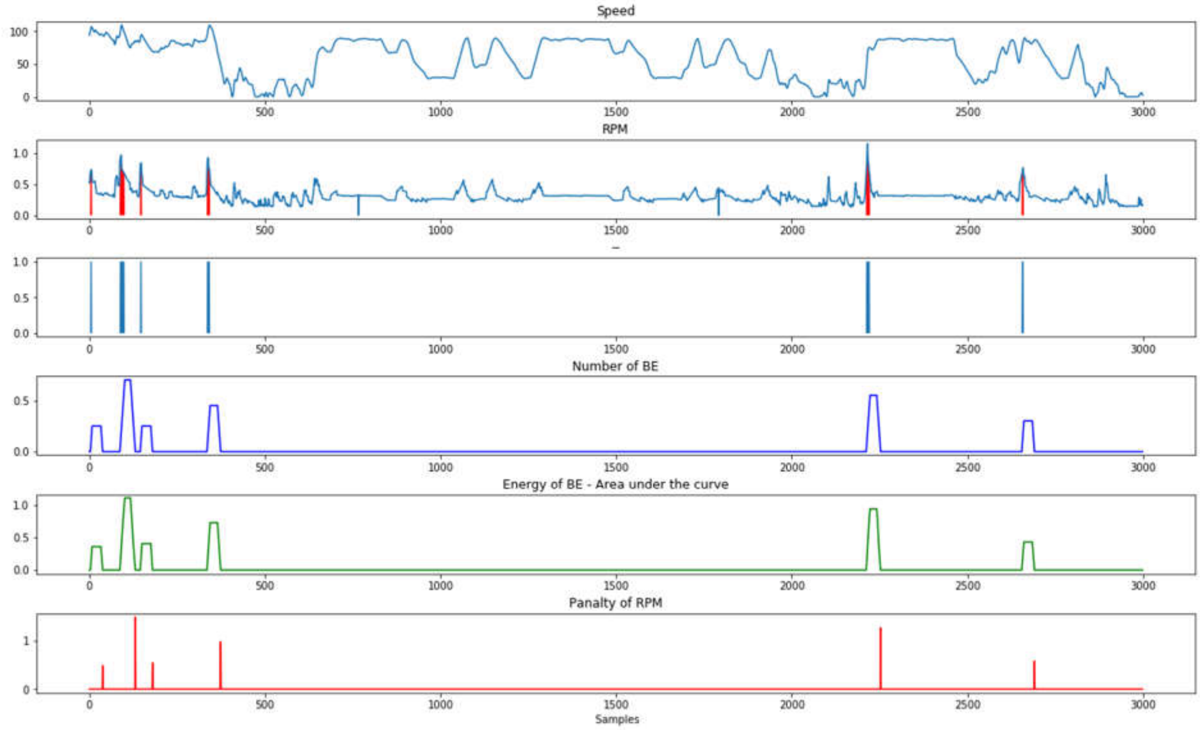


Figure 26: Penalty calculation of Engine RPM

The fig. 27 shows lateral acceleration evaluation, the values which are higher or lower than the range threshold are getting calculated for are under the curve in that region and then penalty for each case is getting calculated.

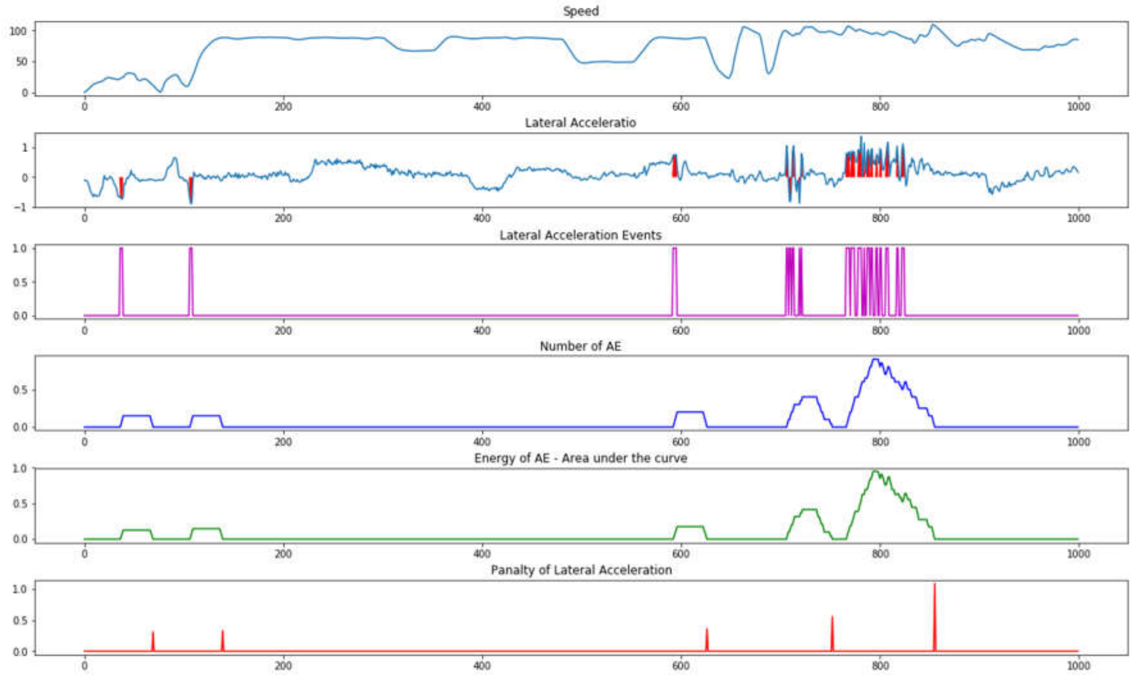


Figure 27: Evaluation of Lateral Acceleration with sliding window and floating thresholds

5.4 Evaluation of Vehicle Driver Performance

In evaluation scheme, driver is considered to be in one of two window, either driver is in green/safe window or red/penalty window. The magnitude & duration of non-green events would be the real contributors in penalty increase. We conducted few tests with FIAT car test driving team experts, and collected different sample cases of driver patterns capturing the events. Expert advises were generic, but could provide a generic range of signals when event happens which includes Harsh braking, safe braking, smooth acceleration, jerky acceleration, smooth steering wheel movement, jerky movements, best operating RPM and worst operating RPM. With these known events, observed signals and advises from experts Centro ricerche FIAT test driving team) about these values and by few more sample cases continuously mail communication, we estimated certain thresholds which can decide if given signal value should fall in penalty region or award region. The list of normal Green or Good Events would be: Smooth Acceleration, smooth deceleration, Engine RPM speed is in range, in range movement of Longitudinal and Latitudinal movements of Car. The Penalty events are Harsh Acceleration, Harsh deceleration Pattern, High Engine RPM with speed and gear, huge deviation in Longitudinal and Latitudinal movements of Car.

5.4.1 Time of Evaluation

Algorithm implementation is tuned for 2 or 20 signals in 1 seconds, which gives information of Driver performance. Algorithm considers 40 signals dynamic window, to evaluate the performance of driver at any point of time, so, have track of past 20 seconds. When user applied brake or Acceleration, this window is good enough to capture whole action sequence.

The evaluation is continuous, in real time, user is getting evaluated, and every harsh behaviour is an affecting factor to score and warning/guidance to the driver. The score update is timer based, but harsh event update to the server is dynamic and immediate. So, significantly harsh deceleration pattern, acceleration patterns, Longitudinal and Lateral movements are immediately get sent to the server, and can see it on Google Map, on SG-CB android application. For each competition instance, there are multiple drivers participating in the competition, each driver sends partial scores on regular interval, and events as they occurs. The server calculates the partial scores to generate final score when individual driver finishes the competition.

Due to their own limitations of CAN bus issues, BMW Car and FIAT car Acceleration values were unavailable at the testing spot. Whereas for Mercedes Benz Car Longitudinal were not available.

5.4.2 Evaluation Configuration Parameter Tuning:

To get the real signal data and understand the relations between different signals and their affects and effects on general evaluation model, collected the signal data of Mercedes Benz, FIAT and BMW and manually analysed the driving with experts. The ranges of signals of each car module were different, and by performing normalization, worked on a standard algorithm and product bundle which can run over all car models with minimal configuration changes. Also used clustering algorithms and signals processing methods to determine, how signals relativity changes over different signal values. Developed evaluators consider signals ranges, their optimal values, and their nature of change, their relativity with other signals.

Car signals independently cannot give correct analysis, for example RPM does have a relationship with speed and gear values, as well as, brake values can be seen harsh when speed values are high, but with low speed values, high brake value is considered to be normal. With this analysis I started correlating the signals to each other and analysed the relationships with each other.

5.4.3. Competition Instance and Participation of Users

For each competition instance, there are multiple drivers participating in the competition, each driver sends partial scores on regular interval, and events as they occurs. The server calculates the partial scores to generate final score when individual driver finishes the competition. Generic evaluator for different car models was one of them important goal, and this was achieved by generalizing the signals. The Generalization car actually make signals in range of 0 to 1 , but the nature of signal stays different for different car models, the rpm range is not same for all car models even after generalization, so having this analysis with different car was an important analysis.

I developed basic algorithm called Linear Distance, and works on threshold theory of signal. When signal cross the value range of its normal behaviour, also referred as threshold limit, the signal sample is considered to be harsh. So, whenever this harness is observed it is getting calculated against the threshold for absolute difference. More the absolute difference, more penalty score is calculated for the sample. The signal evaluation using this method, could give us some entry level results to understand if driver is driving optimal or some harsh manoeuvres are getting performed.

6 Evaluators

This chapter explains developed evaluators for vehicle driver performance evaluation in real-time. The developed evaluators are either java JAR bundles running in OSGi environment in car or Smartphone phone application developed in java for android platform. The OSGi environment bundles real Controller Area Network (CAN) data, which exposed vehicle data. In case of smart based evaluator the raw sensor information is getting processed to find out real manoeuvres of the driver. This chapter will discuss more about these evaluators.

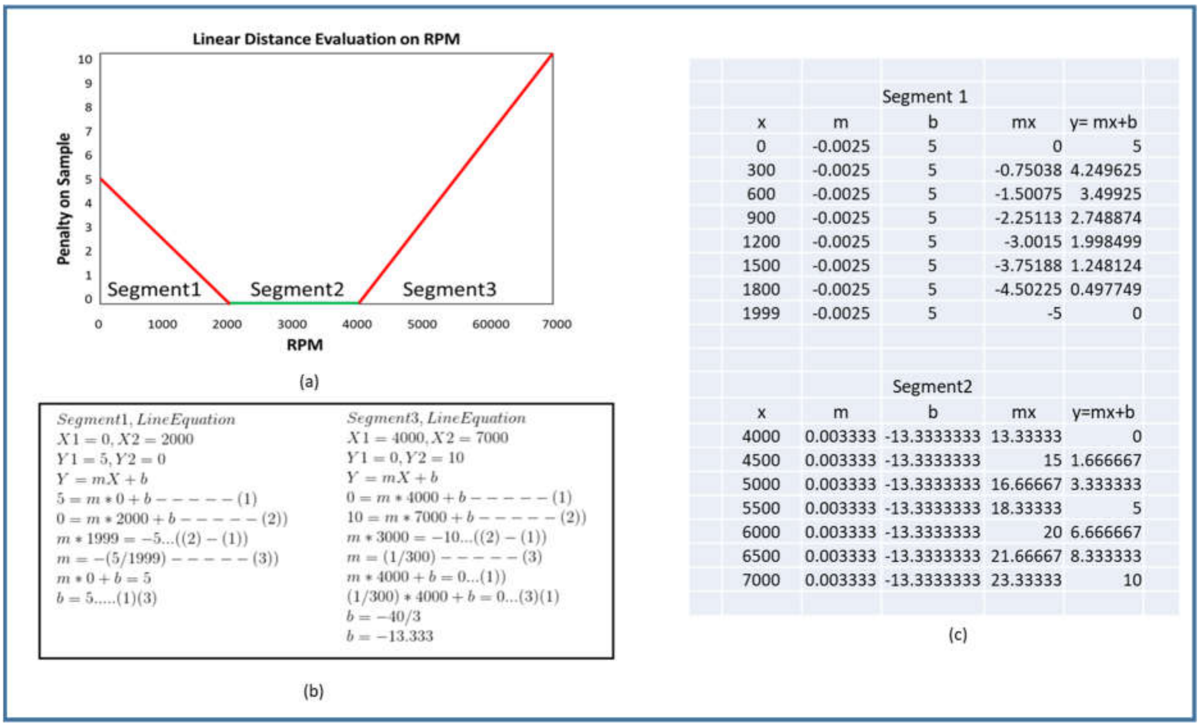
City traffic v/s highway evaluation:

In product code, it was important to provide attention on road traffic, which significantly affects the values of signals and thus a single sample set can not cover all possible conditions. To know whether driver is driving on highway or in city roads, three main parameters were used which approximately determine the road conditions. This process uses signal data of last 10 mins. This data includes average driving speed , total number of seconds with speed was less than 5km/h and the number of times speed goes below 15km/h from speed 30km/h. As total number of seconds below 5km/h goes high and number of times vehicle speed changes from 30km/h to 15km/h goes i, it can be approximately understood that the vehicle is travelling on a traffic roads. There is no clear boundary of city roads and high way roads but according to this calculation algorithms select required configurations. On every 5 mins interval algorithms check this to determine the road environment and accordingly configuration file updates.

6.1 Linear Distance

The linear distance holds a thresholding based evaluation in which every single signal is processed and evaluated for harshness. The metrics for evaluating harshness is devised using the linear equation from which the certain criterion forming the boundaries for penalty and award regions are derived. Considering other matrices of distance calculation Linear Distance provides the output in expected range without much of conversion.

$$y = mx + b$$



Segment1, LineEquation
$X1 = 0, X2 = 2000$
$Y1 = 5, Y2 = 0$
$Y = mX + b$
$5 = m * 0 + b - - - - - (1)$
$0 = m * 2000 + b - - - - - (2)$
$m * 1999 = -5...((2) - (1))$
$m = -(5/1999) - - - - - (3)$
$m * 0 + b = 5$
$b = 5.....(1)(3)$

Segment3, LineEquation
$X1 = 4000, X2 = 7000$
$Y1 = 0, Y2 = 10$
$Y = mX + b$
$0 = m * 4000 + b - - - - - (1)$
$10 = m * 7000 + b - - - - - (2)$
$m * 3000 = -10...((2) - (1))$
$m = (1/300) - - - - - (3)$
$m * 4000 + b = 0...(1))$
$(1/300) * 4000 + b = 0...(3)(1)$
$b = -40/3$
$b = -13.333$

Segment 1

x	m	b	mx	y= mx+b
0	-0.0025	5	0	5
300	-0.0025	5	-0.75038	4.249625
600	-0.0025	5	-1.50075	3.49925
900	-0.0025	5	-2.25113	2.748874
1200	-0.0025	5	-3.0015	1.998499
1500	-0.0025	5	-3.75188	1.248124
1800	-0.0025	5	-4.50225	0.497749
1999	-0.0025	5	-5	0

Segment2

x	m	b	mx	y=mx+b
4000	0.003333	-13.3333333	13.33333	0
4500	0.003333	-13.3333333	15	1.666667
5000	0.003333	-13.3333333	16.66667	3.333333
5500	0.003333	-13.3333333	18.33333	5
6000	0.003333	-13.3333333	20	6.666667
6500	0.003333	-13.3333333	21.66667	8.333333
7000	0.003333	-13.3333333	23.33333	10

Figure 28: Linear Distance Evaluation (a) Graphical representation of thresholds (b) Line equation calculation for each segment (c) Values of penalty with different values for RPM where x is RPM and y is Penalty

Fig. 28(a) shows linear distance evaluation using The slope (m) and intercept (b), where values m and b, for the linear equation are supplied through the XML file and from which the penalty values are calculated. Then snapshot shows the values which are resulted from high way driving pattern, ASTA Zero, Gotheborg, Sweden was the drive reference for this values. In city roads, the range is expected to change. According to this values the range values for differerent segment changes. The processing of RPM signal using linear distance approach, the entire space is divided into three segments (segment 1, segment 2 and segment 3). Considering there are 2 regions with penalty 2 pairs of values for m and b are provided using xml file, and calculations of line euqations are explained in fig. 28(b). In this three segments, each segment holds the set of limits such as segment 1 has the limit from 0 to 2000 and segment 2 holds the limit from 2000 to 4000 and the values exceeding 4000 will be gathered in segment 3. Let's assume that the engine RPM is around 1200, now this signal would fall in segment 1 where the limit ranges from 0 to 2000 and it is considered to be less than optimal RPM penalty will be 3. In another case let the RPM is 3000 which falls in segment 2 and thus will not have any penalty, in another case RPM value 5500 will fall in segment 3, and penalty calculation will be 5. Fig. 28 (c) showcase the values in table, where x is parameter, and m and b are slope and intercept decided on the basis of required penalty and y is the penalty output. The signals such as acceleration, RPM, brake and speed are evaluated using linear distance in my approach, the results of the evaluation will be sent to the virtual coins and competition server.

As shown in Fig. 28, with any possible value in the mentioned range of RPM i.e. 0 to 7000, resulting value for y will be from 0 to 10. The other matrices can be used where value and penalty does not change in proportion and possible to use where signal values, but we did not improved this algorithm toward this directions using and chosen more correlation and regression techniques to find better alternatives for this method. Although logarithmic, exponential and quadratic procedures can replace linear distance approach, thses changes themselves are not suitable for multivariable correlation.

6.2 K-NN (Nearest Neighbours)

Another evaluator used was K-NN, which is a classification approach. The significant reason for using K-NN is to map the relativity between the speed and brake signals and to penalize when the conflict between them increases (Example: when the vehicle is at high speed, the brake should be applied minimally. If the driver applies high pressure brake, then the action will be highly penalized). The knowledge of particular driver is good or bad was available due to experiments and related time signals where available which could provide details of particular behaviour and raw signal values at those moments. Even with minimal signals this is possible to perform heuristically, for multiple signals this become tiresome task. The samples of harsh patterns are supplied as a training set to the algorithm and from which the specific harsh values are picked up and penalized. The signals such as speed and brake values are supplied as inputs to the algorithm and the harsh patterns of these signals are provided as a training set to the algorithm. As in fig. 29 In the K-NN Implementation here, K=1, that is nearest neighbours reference used to calculate the penalty for the single signal value. For each signal value, the algorithm refers to the sample set to calculate penalty value. The reason of having k=1, is already known relation between signals, range of signal values and threshold values. So, have a control on penalty and award values and they can be set as per the changes in the criteria. This gives the possibility of customization to change expected conditions and deviations. K-Nearest Neighbours approach can evaluate the relativity of more than one signal at the same time, such as Steering wheel vs. Speed and Steering wheel vs. brake.

Figure 29: K-nearest neighbour Evaluation

KNN Implementation and Consistency with multiple car models:

Then KNN analysis was performed in python for offline files, and product code implemented in JAVA jar bundles for OSGi environment to execute in the car. The primary observation available from offline analysis were used to create multiple sample sets for different traffic conditions which include city traffic and highway traffic as well as for different car models. To differential between the city traffic conditions and highway conditions, last 10 mins of present vehicle signal observations determine which sample set should be loaded into memory. Algorithm implemented in java OSGi jars, the sample data sets where .csv files, which are according to primary offline analysis of car. The algorithm used ArrayList of raw signal objects which are updating with real time current signals. Only last 10 mins of data was stored in ArrayList for processing, and few of them used to update the sample set if criteria meets. New signals also contribute in dataset, although update of dataset sample is minimal. For any new signal, when resulting cluster has close competition for different clusters due to close Euclidean distances, that signal data considered to be important in future classification and gets appended to file with allotted cluster.

The consistency of classification is achieved by limiting update of initial dataset with minimal new information. So, even with every new signal values dataset does not get biased. The data structures used is ordered ArrayList of signal pack where class attributes are different signals used for KNN and order is based respective to most relevant attribute. Also have implemented few optimizations outside the algorithms which avoids comparing each new signal with sample set, and only compares signals which cannot be decided with heuristics operations.

6.3 Dynamic Sliding Window

Choosing the Size of Static window:

It is difficult of find out the correct size of the static window to evaluate the driver. As having very small window results in multiple calls to server for update as well as there are many chances that results shows exaggeration in user scores.

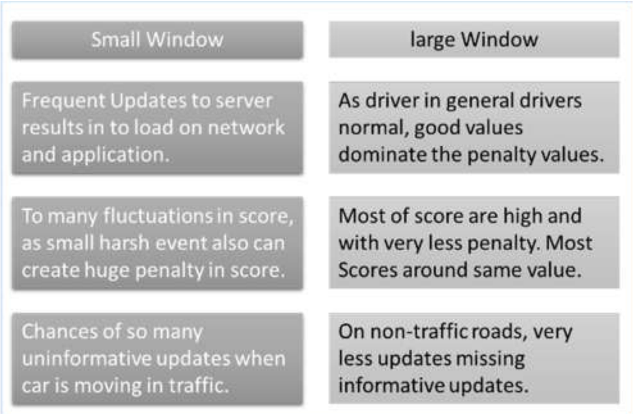


Figure 30: Selection of n-sample window

Before the approach of Dynamic sliding window, Evaluator consider every 20 samples for signal value as a static window, but has any problem in selection of window as depicted in fig. 30. These windows are non-overlapping, and each stays valid for 20 seconds considering 1 sample for a second. Every window is responsible for evaluation of those signal samples. The Static window comes with the results on every 20 second interval. The interval of 20 second is chosen against 10, 15, 20, and 25,30,35,40 because, it can successfully catch brake acceleration and steering wheel events. Another reason was to provide results to the games implemented by another team in my lab using this framework. For those 2 games driving evaluation results where expected in continuous intervals of 20, 60 seconds respectively.

Dynamic Sliding Window is an event-based signal evaluation. The algorithm comprises of two states (i.e.) standard window and penalty window. As represented in fig. 31, this implementation, the Dynamic Sliding Window is evaluating every single Signal. When the signals are in optimal range, state is considered to be standard (normal region for signals) and when signal values deviate above from the optimal level, then the state is considered to enter the penalty window. Once the signal starts to deviate above the optimal level, the penalty window starts and remains till the point when it comes back to optimal level. The size of penalty window and the deviation amount in that period of time are the factors which are getting evaluated under this algorithm. For example, if the user exceeds a particular speed limit, then the state changes to Penalty window. For FIAT Acceleration signal, simple snapshot is showin in Fig. 31. The above 40 acceleration pedal value is considered to be harsh, so, when acceleration value goes above 40, the penalty window starts and remains till it goes back less than 31. In case of value less than 40 algorithm calls that signal status to be in normal window.

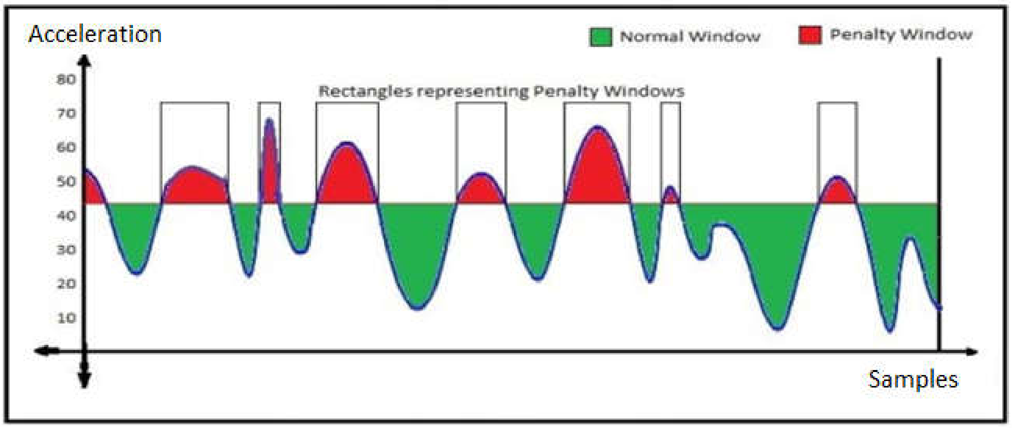


Figure 31: Penalty Calculation basics of Dynamic Sliding Window

The concept of Dynamic sliding window is to remove the drawbacks of both the cases of Static window. With Dynamic sliding window, the major observation of the evaluator is on harshness of the signal values. When signals goes high in value than an average value, window starts and till the point value is higher in magnitude window stays open. Once values comes back to its normal range, the window gets complete. Basically there are 2 alternative windows in Dynamic sliding window for each signal which are Penalty window and award window. The Award window is a normal range of the signal where as Penalty window is harsh values. Any new value coming from sensor with all conversion either can be in penalty zone or award zone. As shown in fig. 32, according to next sample value the window changes, if window changes from penalty to award, then total penalty calculated is considered as penalty of the window.

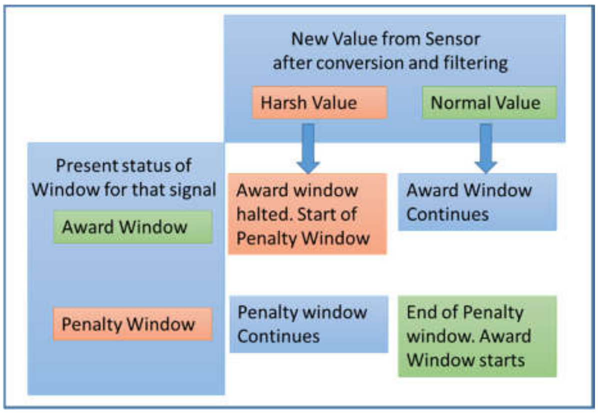


Figure 32: Award window & Penalty window transitions

6.4 Fuzzy system based Dynamic Sliding Window (FDSW)

The evaluation methodology has two approaches: the first approach involves the direct estimation, by individual signals such as latitudinal acceleration, longitudinal acceleration, and RPM. To understand the harsh brake patterns of the driver, the second approach in estimation process involves the mapping of conflicting signals (steering wheel angle and speed) with brake. For example, if driver tends to apply harsh brake with high steering wheel angle, then it is considered as the highest level of harshness. In Fuzzy based logic, the maximum value of each signal is used to normalize the forthcoming signals of the same type from the vehicle. The normalization is done in range of 0 – 1, which allows using fuzzy logic and calculations. Fig. 33 shows signal can be penalty zone as per threshold level, this threshold limits determine the penalty and non-penalty zones for each signal type, and it varies as per new data and results. As If user is not having any penalty in last n samples (n is number in thousands) then penalty window threshold drops slightly. If in m samples (m is in hundreds) user behavior is having so many penalty cases then threshold sighly rises. This process helps in determining correct threshold lever for each car model and can even work with new car models. The learning rate is kept inversely proportional to number of samples, so once the initial training has correct behaviors and correct expectation of event thresholds, new entries can not change the treshold with huge margin, and this helps in being trurshworthy evaluations. To find threshold using log and known events, I took each signal into account. Considering the whole signal stream, keeping track of the maximum, minimum, average, median and mean values threshold can be traced, although few on-site real time tests serve a great purpose.

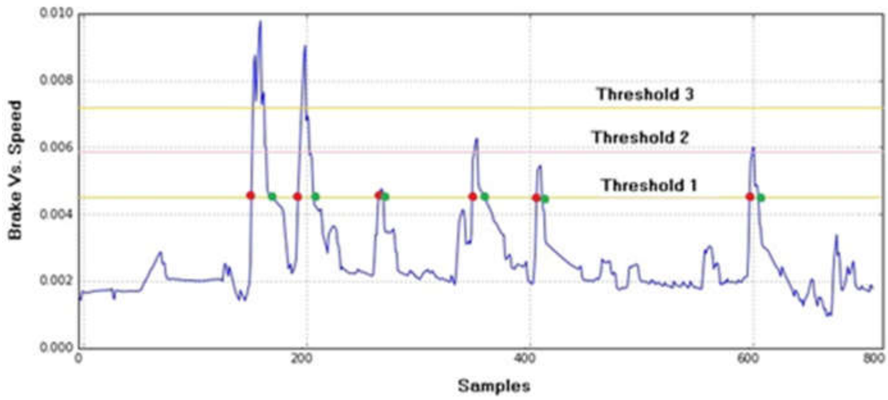


Figure 33: Threshold levels and penalty change analysis

I have used binary search for evaluation method with different methods on log files to find the correct threshold for any signal. Although here main goal is not to reach a single correct value for the threshold, but a short value of range of possible thresholds, and this process run offline even before on-site evaluations. Using the threshold range, real time test easily can provide a correct threshold value in few minutes of driving. The algorithm finds penalty windows for that particular log. If the outcome of algorithm matches to the previously known data, then the threshold is stored for future use. If the outcome is higher than expected then the lower half of problem space is neglected and search happens in the upper half and vice versa happens when the outcome is lower than expected. The algorithm processes the threshold-1 and finds six events in the log, but as per expert given values, only four events of brakes are applied. So now the algorithm tries to find threshold in the upper half and selects threshold-3. With threshold-3, the algorithm finds only two events and again the search happens in lower half of problem space. Now the threshold-2 is captured and it has four events, (2-harsh and 2-medium events).The search completes and threshold with value 0.006 (Normalized) gets stored for future use.

To estimate the proportion of penalty, the evaluator module checks for three features: number of signal samples that got captured in penalty zone (width of penalty zone), maximum peaks found in penalty zone (height of penalty zone) and the sum of samples above threshold in penalty zone.

All these three features have different weights in the final calculation of penalty for every signal category. The final penalty will be estimated based on the magnitude of the three features associated with penalty zone. The raw vehicle signals are normalized in range on 0 - 1. This normalization aspect helps to generalize vehicle signals for evaluation module, in such a way that the algorithm can adapt towards any signal range of a vehicle. Because the signal range depends upon vehicle (manufacturer, model, etc,) and the evaluation algorithm should have a tendency to adapt towards it.

Once the correct threshold is calculated with highest level of matching of number of events with manual expected of events and algorithm output, then as represented in fig. 34, intensity of event can be evaluated using Area under the curve, high peak value in penalty zone and number of samples in penalty zone.

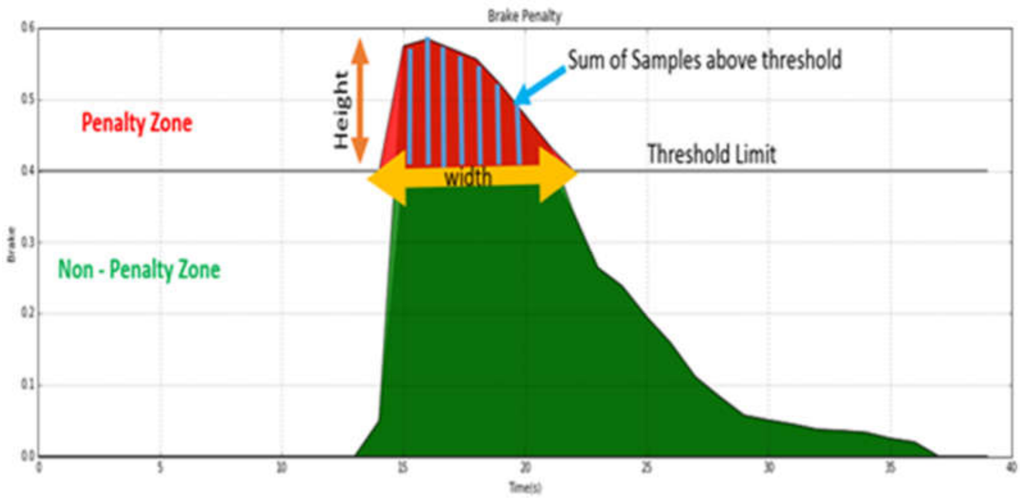


Figure 34: Area under the curve in Penalty Window

I requested the expert drivers, to provide test drive logs with few harsh driving events (harsh brakes, jerky accelerations and high RPM) in each ride and to mention event count. The ride log is approximately 20 minutes and it has raw data of vehicle signals at the frequency of 100 milliseconds. Each log is paired with event information given by drivers about a number of events in that particular drive. So well in advance I analysed the information about the drive. Using the logs and known data paired with each log, trained the algorithm to find correct thresholds for each signal. Having multiple drive sessions resolved the issue of biased evaluation. By average values, threshold has got setup but still in future rides, according to new values threshold gets automatically adjusted according to changing threshold criteria to restrict any false tuning.

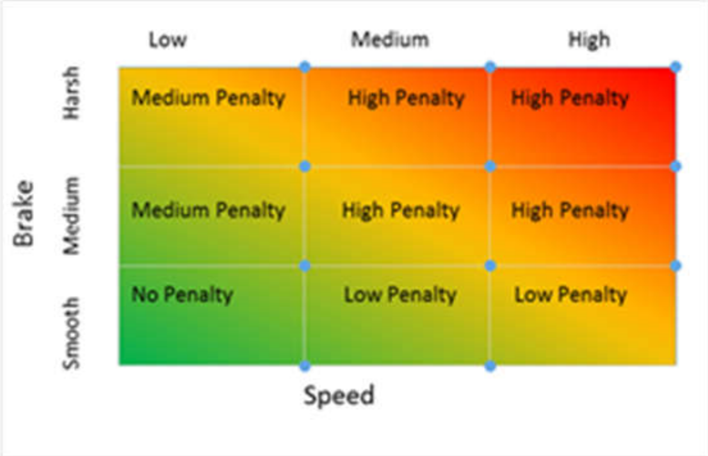


Figure 35: Correlated signal influence on penalty levels

The FDSW maps the fuzzy rules based on the penalty intensity map represented in Fig. 35. Thus by associating brake along with speed signal, there can be a more meaningful analysis of harsh driving patterns. Higher the speed, the weight of penalty is more even if brakes are applied at a medium level. With low speed, the harsh brake will not contribute for more penalty.

Comparisons

Linear distance does not take care of more than 1 signal in correlated, whereas dynamic sliding window can consider n number of signals. KNN is suitable for more than 1 signals in correlation. So, speed versus steering wheel, rpm, brake comparisons are possible for different inputs of the signals. But, KNN can't take continues signals into account and works only on 1 signal pack with multiple signals. Whereas Dynamic sliding window is suitable for multiple signals and continuous values. But, due to number of signals and their magnitude resulting penalty of dynamic sliding window has excessive range which create big challenge to convert the score in range of 0 to 100.

Fuzzy based dynamic sliding window deals with issue in dynamic sliding window by having a signal range domain for each signal from 0 to 1.Thus normalization and fuzzy set rules are used to keep outcome of evaluation in range of 0 to 1.

6.5 In App Evaluation Implementation using FDSW

In-App Evaluation needs Drivers smartphone running evaluation app and fixed using phone holder. The Evaluator app running on phone, users phone sensors such as accelerometer, gyroscope, and longitude latitude position.

Gyroscope – Steering wheel angle, and latitudinal displacement.
Accelerometer – Acceleration and Brake
Latitude and longitude – GPS location on a map and Speed calculation using distance against time formula.

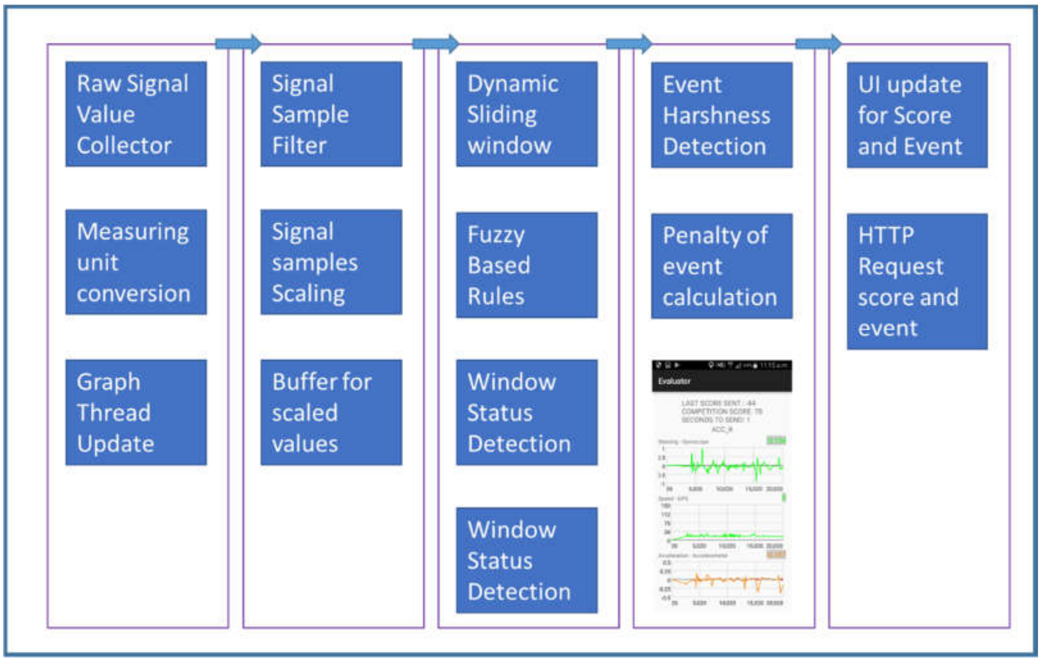


Figure 36: Smart phone evaluation pipelines and multithreaded implementation

So raw sensor values travel in pipeline of unit conversion, filtering, scaling and then real usable values become available for the real evaluation. The fuzzy based rules related to each signal evaluate the degree of harshness of any signal with their related signal values. This computer values then used as numerical value of penalty for each sample. The evaluation algorithm for smartphone is same although the raw signals are different in frequency, ranges and number of dimensions.

As only 2 sensors and GPS longitude and latitude is available, there is lot of computation required to get more details like speed using time and GPS coordinates and then Acceleration using Time and Speed.

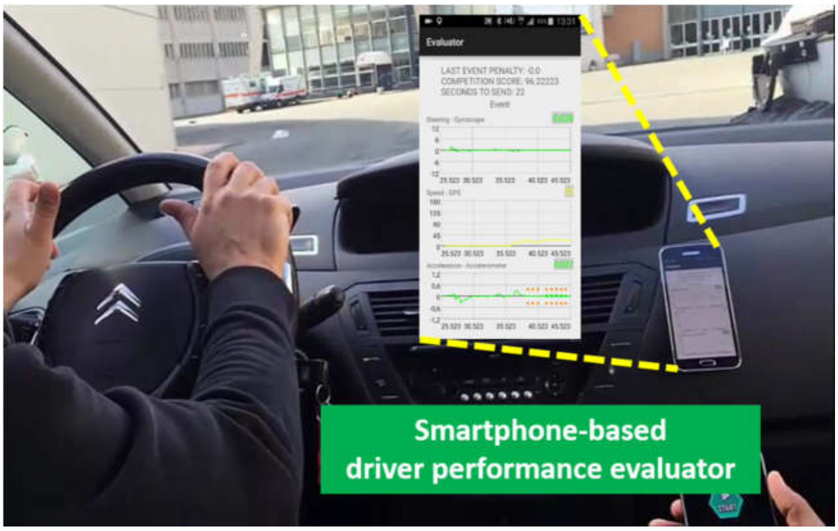


Figure 37: In-App Evaluation Test

The Application uses sensors for getting raw sensor signals for understanding the car manoeuvres accordingly on every 125 millisecond interval. As represented in fig. 36, Application read new set of raw signal data, from the sensors and fills it in buffer for displaying them on Graph on screen, and to evaluate a driver performance with score and events information. To make this sensor values usable in programming measuring units conversions are taken place, so, time can be counted in seconds, speed in km/h, acceleration in velocity and time, gyroscope in degrees per second.

On Application these values gets represented as a graph as a visual feedback to the user. Every batch of 8 signal samples then gets filtered in a single sample for reducing the noise. So, application get 1 sample in 125 * 8 = 1000 milliseconds, i.e. 1 second interval. Feature scaling is used to standardize the range of different signal samples for normalizing the data in values from 0 to 1 range. The scaler here uses historical values of min and max, and also update in case of new value from min or max is found. Evaluation uses a concept of window, which is a set of n signals samples. There are 2 types of this windows are used: Static Window and Dynamic Sliding window. As shown in fig. 37, the driver has to mount the phone, and sensor values gets used by the evaluation algorithm for evaluation of the driver performance.

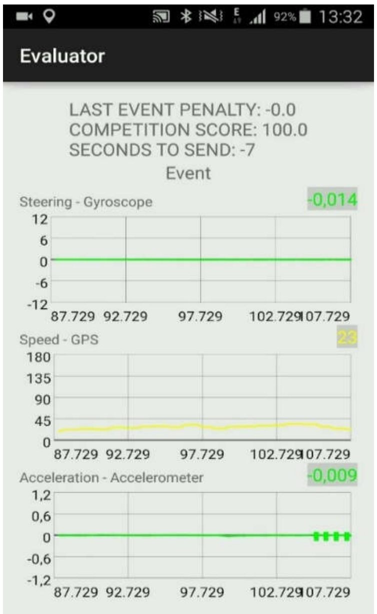


Figure 38: Smartphone Evaluator Graphical Output

Fig. 38 shows the Evaluator screen, there are 3 visualization graphs, each for Gyroscope, Speed and Accelerometer. The harsh even shows signal wave in yellow and red colour according to harshness of the event.

Fig. 39 shows the events labels used in the framework for different harsh driving events. There are 3 main categories: Brake, Acceleration and RPM. All evaluators mentioned in this session uses same labels to represent some event on map. The Brake also have 2 sub parameters: Speed and Steering wheel angle. The intensities of harshness are Yellow and Red, sometimes Orange replaces Yellow in representations.

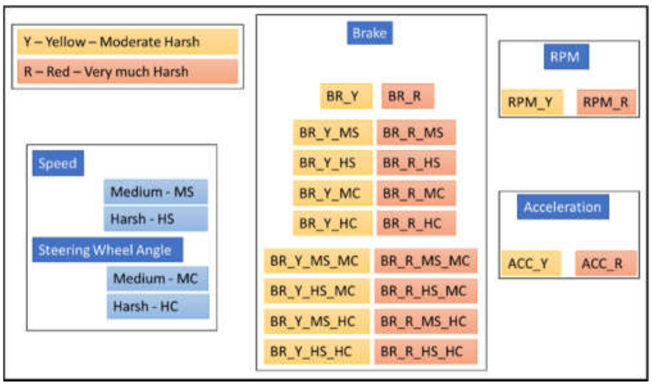


Figure 39: Harsh Events in vehicle driving

7. Gamification and Performance Visualization

This section discuss about visualization of performance evaluation of the users for the purpose of awareness and motivation. The section covers the Applications which have got used in this framework, types of visualizations and infotainment availabilities and future possibilities.

7.1 SG-CB Application

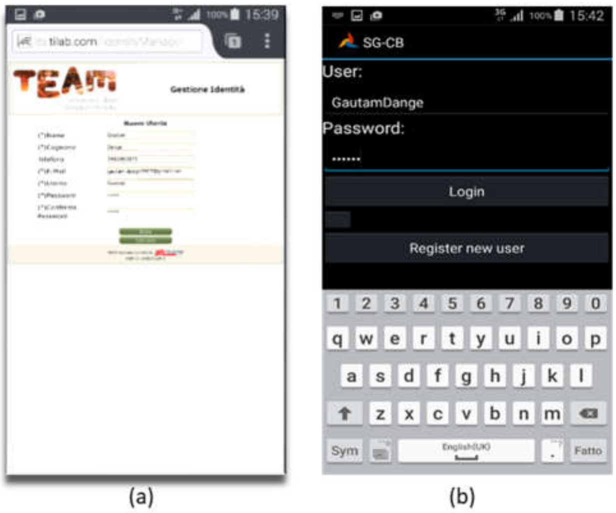


Figure 40: SG-CB application signup and login

Once user logs in to the Application (refer fig. 40) he/she can subscribe to the competitions he/she want, and also can check the scores if user has already subscribed and participated in the competition. The user can see his performance not only as a numerical value but also in form of graphics, statistics and games (refer fig. 41).

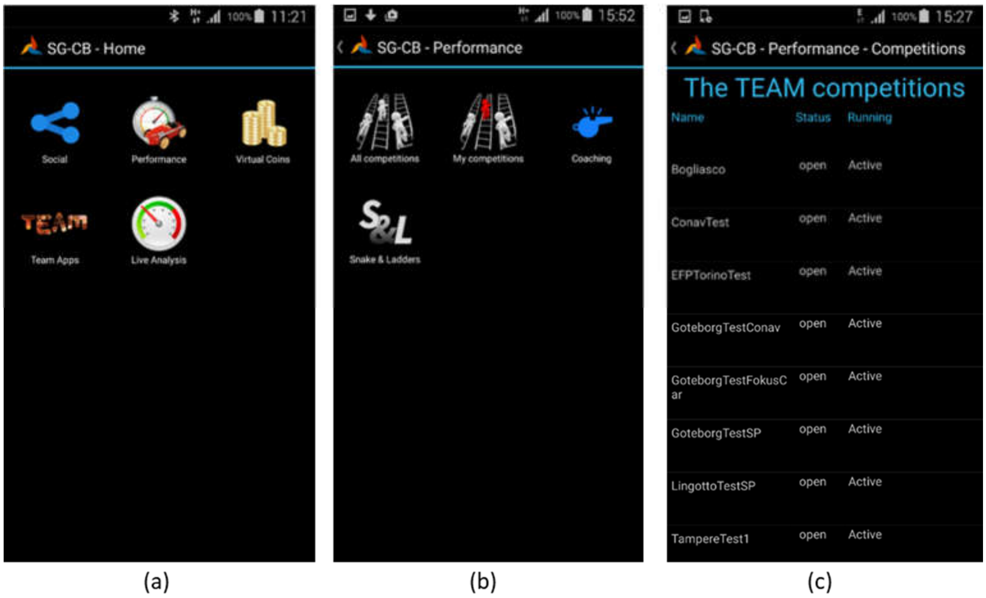


Figure 41: SG-CB home and performance results

The user can check his competition score, and other users' score in that competition (refer fig. 42). User can also see the harsh events in his/her driving on google map, with event details, longitude and latitude information. The events are Brake, Acceleration and RPM which have discussed in Vehicle driver evaluation session. The user can also check who the winner of the competition is.

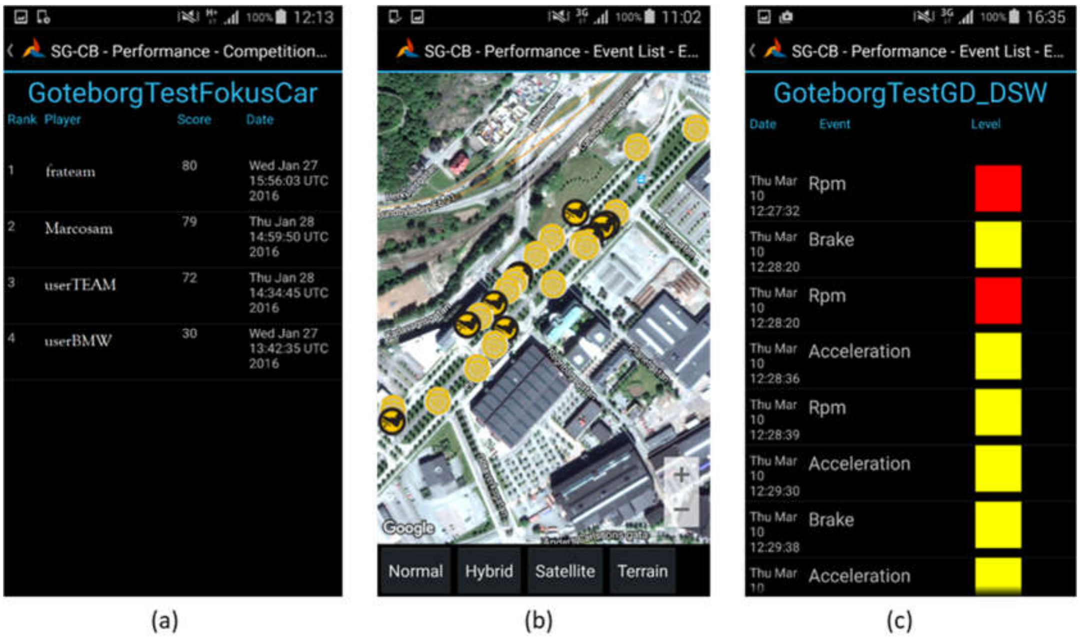


Figure 42: User Scores and Events in Competition Goteborg, Sweden

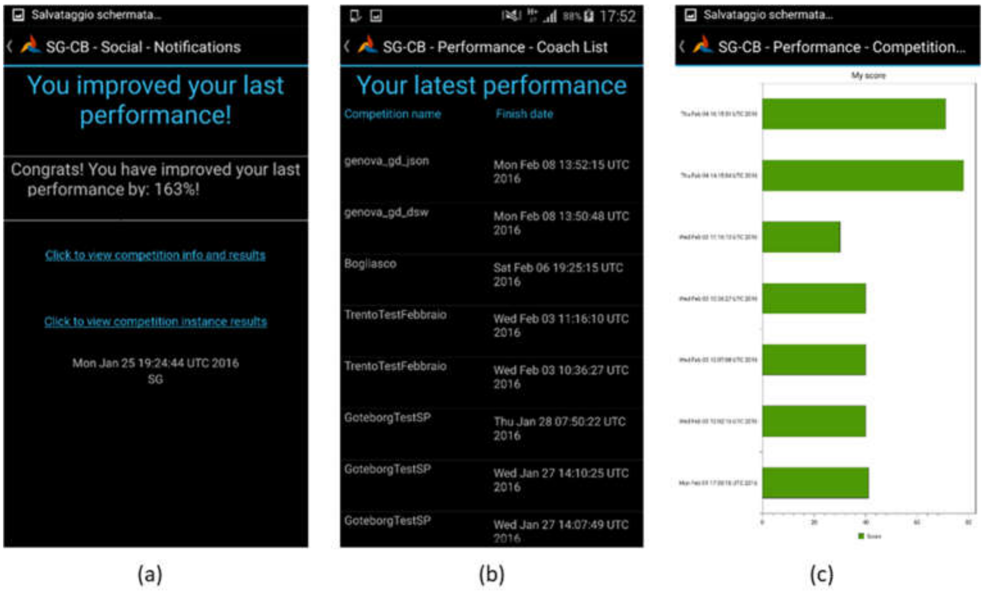


Figure 43: Notifications about improvement, historical records and latest performances of user

As Fig. 43 shows The user also get some notifications about his/her better or worst performances in recent days and also can see the information of past competition performances. This information helps user to feel motivated, and perform better in future. Awards also has an importance if they are achievable and to get an award by winning user is not required to do something special, but just keep driving green.

7.2 Gamification:

More than having a static and passive information, the user results of Green Drive competition are also getting used in Games as an input to change the environment. The games developed on this are out of scope of this thesis, but this section will provide some information about how games can be converted to Serious Games, with minimal effort. The Server exposes few RESTful APIs which game designers can use to get drivers partial score on regular interval whenever he/she is driving. The user score gets sent to the server by evaluator on every 20 seconds, so, when user is in competition, his driving evaluation score is available in server till driver is driving inside the competition, and car is having speed more than 0. This regular update of score to the server, is available to the game designers for using in their games. By registering in TEAM site, the game designer can browse the different evaluators and their frequencies of score update. The evaluators also can have many different types, and can even have different motivation other than Transportation domain. The implementation of Evaluator and Gamification modules is completely independent of each other. The Application Programming Interface API for evaluation and gamifications will be used for perspective task of sending score to server and receiving score from the server.

Gamifications has got implemented by fellow research team using this framework. Basically framework allows using data of user evaluation with different types and frequencies. This types includes 1) immediate feedback 2) short interval feedback 3) periodic long interval feedback 4) daily summery 5) weekly status report. The games can use these types according to their expected frequency of score input as an energy factor. Few games implemented in my lab are 1) driver game 2) passenger game and 3) snake and ladders game. The Driver game uses the immediate feedback and short interval feedback. When driver gets evaluated, event and score information gets transferred in real time to server. Then server sends the event data as a part of immediate feedback and also sends score updates on every 5 seconds as a part of short interval feedback. The driver game has an access to those scores and game responds to the driver with audio note about his/her harsh behaviour and continuous driving evaluation according to short interval feedback scores. The passenger game uses periodic long interval feedback with uses 20 second interval for driver evaluation and game environment changes accordingly to the score, and game is played by passenger or any other person than a driver. The example of passenger game used in our case is father/mother is driving a car and his/her son/daughter is playing a space shooting game at home. The game environment difficulty changes according to driving, thus harsh behaviour raises game environment difficulty by adding stronger enemies and good driving supports player with extra health points in game environment.

7.3 Possible Achievements

7.3.1. Awareness and Coaching:

The immediate feedback about the performance allows pin-pointing exact wrong driving action performed by the driver at any given point in the driver. Thus these feedback messages immediately gets converted in to audios makes driver aware of the wrong action he/she had applied before couple of seconds.

7.3.2 Motivation:

Framework allows social advertisement of the winner of the competition in the local region other than just allotting some reward. This advertisement create another social influence in the geographical region. This history of performances of the drivers is expected to have some impact when community of drivers who wish to take part in green driving practices starts addressing some people as good drivers. Although this things have not got focused specifically and will be addressed in the future work.

7.3 Types of Gamification Mechanics:

(i) Score/ points

It is a periodic calculated score of driver in a given time. Generally time period is decided by the evaluator designer.

(ii) Virtual Coins

When driver wins particular competition he/she gets awards with virtual coins, which is virtual cast award and can be used in multiple ways like purchasing fuel, bus tickets etc.

(iii) Awards

Other than virtual coins, other awards can be given by competition designer.

(iv) Notifications

When harsh move is performed by the driver, driver gets notified by the audio message about harsh move as well as his good driving manoeuvre. Notification also used in advertising winner. Notifications are used when user performs better than his/her historical performance.

(v) Leader-boards

(Advertisement of winner on the SG-SB Application Dashboard)

When some driver wins the competitions in his/her geographical area, this names gets displayed on the SG-CB application dashboard of people in same geographical zone.

(vi) Events visualization

More than having just a score for his/her driving driver can check his harsh actions on the road on google-map using SG-CB application.

(vii) Progress Tracking

The game has audio feedback and has got developed by University of Genova Research team which uses audio feedbacks to driver on occurrence of harsh events. It has certain levels and user can completed those levels only if he/she keeps driving green consistently. User can see his/her progress whenever he/she is not driving.

(viii) Games with level and Unlocking new levels

The passenger game uses driver's scores, in space shooter game. The person who is not driving the car is expected to play this game. But other than his/her own game skills, drivers driving performance affects the game environment. So, with better driving driver can help passenger game player to win in a game. Game has multiple levels and driver can complete level with better performance over the time.

(ix) Game with randomness variant

Snake and ladder game

This works on number of competitions won by the user in recent days. The game is simple version of snake and ladder game, but with less uncertainty. The different users keeps advancing to the victory condition of the game, but other than their own efforts little randomness is added in this game, which changes the outcome of the each move with few degree of randomness.

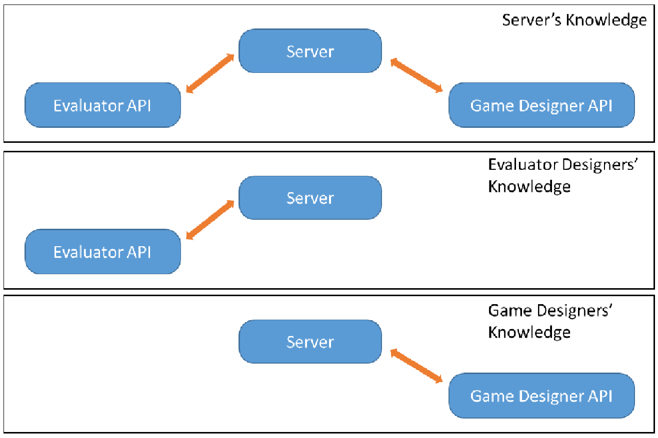


Figure 44: Evaluation and gamification relation and perspectives

Fig. 44 shows the independent development due to framework implementation. When a game designer wish to user the serious data for his/her game, he/she need to sign up to the system and then need to send request to server for evaluator access. Once server grants him/her with evaluator access, it is possible to get the list of available evaluators. Game designer can request the list of available evaluators, number of current users getting evaluated using that evaluator, recently used date and time of evaluation and frequency of score update of the evaluation. The server provides this data to the game designer as a response (Refer fig. 45).

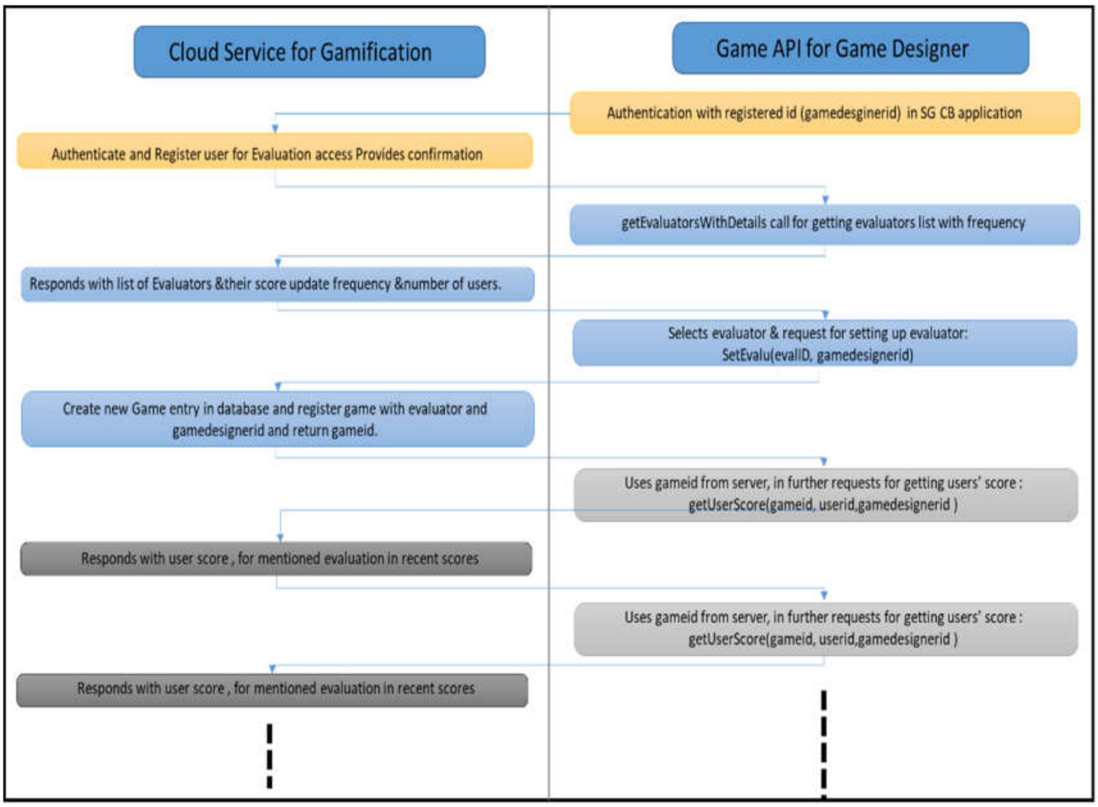


Figure 45: Activity diagram - Game designer using serious data

It is a choice of a game designer to select the evaluator, so, game designer request server to set the evaluator. The server allocate a new entry of game and adds the evaluator and game designer entry for further references. The game designer can access the User ID who are getting evaluated actively, so, game designer can user some users' score as a game input.

Few example games which can be developed easily in few hours using this methodology, few of them are listed below:

- Tom Cat is evaluating you: showing Happy, sad, angry, frustrated reaction according to user score.
- Trek to the mountain: The character in game is hiking to the peak, when driver drivers green character hikes, if score is low, trekker stops due to bad weather, or even trek down, with unhappy mood.
- Score dial, the simple performance visualization using game. User scores gets compared with other users and accordingly score dial shows green or red intensity.

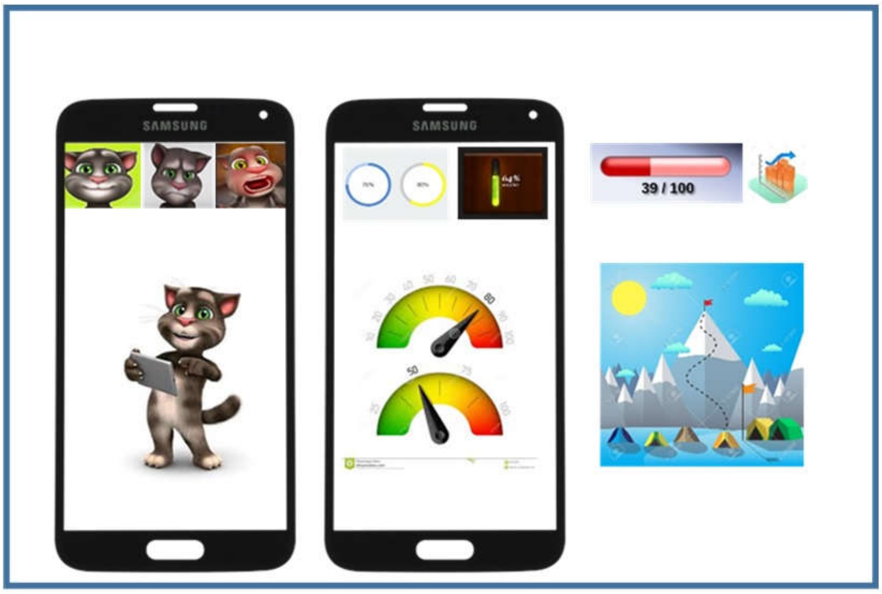


Figure 46: Possible (not implemented) gamification, for new game designers

7.4 Gamifications and its impact on user

To understand the impact of games on the driver as a motivation or training is difficult to understand. This needs continuous evaluation process of the driver and drivers required to be consistently reviewed. But, in this framework, In-car evaluation is still not available to the public, as this is still in development phase. So, presently only vehicle companies has hardware support for in-car evaluation. Whereas In-Application can be used by any vehicle driver, these smartphone evaluators has very limited functionality to test and does not come up enough details to rely on them. Change in behaviour tracking is a long term task, it would require to take few rounds of user-tests to take inputs. So, to find out if serious games for mobility are enforcing the positive change in driving style and whether it stays in them over time, there is a need of continuous experiments-findings-feedback loop with drivers over the period of several weeks or months. This would be discussed in future work.

8. The Cloud and Framework

Tools and applications which can evaluate vehicle drivers driving performance do exist in today's world but in fact these tools and applications are mostly dependent on a single user or implementing them in a team on a comparative measures is not that feasible due to many configurations. As discussed in previous sections, evaluation of the vehicle driver has got implemented, but to make this possible to use it in real time, it is important to make configurations easy for the users. This motivation was the reason for the concept of automatic configuration framework which consist of server modules & Competition manager application which a smartphone Application. This framework allows users to create competitions and invite other users for participation. User can add meticulous details using Competition manager Application and in turn framework can automatically start user evaluation, if user wish to go for it. Framework also create new platform for new game developers who wish to user serious information for the games to make serious games. This chapter will discuss in details about how this automated configuration works.

Table 1: Basic Idea

Evaluators	This table keep the details of evaluators, which includes which data evaluator is it processing, the motivation of the evaluation, and the frequency of updates to server, the owner of the evaluator designer.

User	Any person who is part framework, includes evaluator designer, game designer, competition creator, milestone and timeslot creator and the drivers who are ready to get evaluated for their driving performances.
Competition	Competition is a time and location bounded evaluation of many users for green driving criteria's, and the winner gets the prizes mostly in form of virtual coins. A Competition is comparative analysis of user evaluation for the Green Driving. It has multiple occurrences called instances.
Competition Instance (CI)	As per the competition settings, the competition required to takes place multiple times at the same geographical area, same awards, each of this instance is called competition instance. It a time when competition is open for evaluation till it closes for evaluation. When it reopens it is called as new instance of the competition.
Competition Status	With the setting of competition, when new instance is created either manually or by timeslot settings, Competition status becomes open to receive evaluator results. Competition Instance can be stopped manually or due to timeslot completion, this time competition instance goes off and competition status changes to Closed. There can be overlapping of timeslots in same competition having live timeslot, in that case, competition instance continues and status stays Open.
Competition owner	The person who creates the competition, is the owner of the competition and only has access for adding, deleting or editing milestones, timeslots and awards related to the competition.
Competition awards	Competition owner sponsors the awards for the winner of the competition. This awards can be direct gift or virtual coins in case of TEAM IP 7 project related competitions.

Table 1 explains the basic terminology of Competition. The results from the driver performance assessment (Evaluators) are constantly updated on the MySQL database and the user can access the data using HTTP Post requests by the SG-CB smartphone application or HTTP requester plugin of Mozilla Firefox.

The server accumulates the virtual coins attained by the user and maintains the entire log of virtual coins flow. The gained virtual coins can be spent on the real-world applications such as purchasing bus tickets, reservation of parking lots, etc. The competition server manages the list of competitions, users, subscriptions, etc. The evaluators uses the web service to interact with the server for updating information such virtual coins and competition scores periodically. Evaluators also can request for list of open competitions, badges, total score, and accumulated coins of concerned user from the server.

8.1 Server Modules and Services

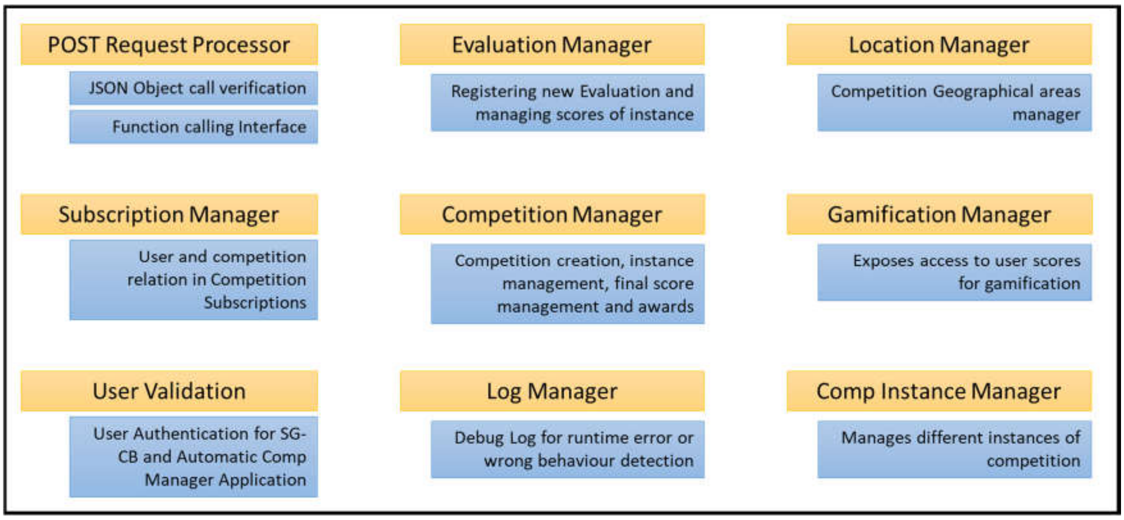


Figure 47: Cloud server modules and services

The Post Request processor module, checks for the correct HTTP request and accordingly calls in other modules for execution of the response routine for responding correct output. The Evaluation manager is responsible for managing the registrations of the evaluation and managing the score of competition instance evaluation with the score given by evaluator. The Location manager managers the competition specific locations, also called as competition area. As competition is linked to geographical area location manager is responsible for finding out county, GPS co-ordinates, and time zone related activities about competitions. The Subscription manager is responsible for competition subscriptions by the users. The users can search for the competitions around them and can subscribe them, as well as competition owner also can send an invite to the users, and if users accept the invitation then they becomes subscriber of the competition.

The competition manager is responsible for managing the creation of instances of the competition and allotting the winner with mentions prizes and displaying them to social dashboard. The User validation is responsible for authentication of the user with ID and Password check. Log manager is internal module and log out important operations on the database other than read. So, in case of error in HTTP request response process, the log is used to find out the problems. The Competition Instance manager is responsible for the instance specific scores, event reported by the evaluator and calculation of the final score from partial scores of particular period for user for the competition when competition instance closes.

8.2 Staged Competition

The importance of vehicle driver evaluation would show its significance when It would be used by many users in the real world. To make it from configured tests to the day to day evaluation platform, some automatic configurations are required. As in real time, drivers can not expected to spend time to configure their phone or car for enrolling them in some specific competition. This chapter will introduce you to the Staged Competition framework, which allows the driver to subscribe to the competitions which are nearby to them by a location, then he/she will be in competition without any efforts. In few clicks, the vehicle driver can subscribe a competition and then each instance of that competition will evaluate his driving behaviour without much of configuration until he/she unsubscribes or competition completes the number of assigned instances.

In an automated configuration competition framework, the Competition having specific route and specific time slot. The route is in fact a path from one location to another location and contain different milestones to be visited either compulsory or optionally. Suppose that there is a competition C, which has starting point A and ending point B. A & B are geographical locations in the city. This locations can be represented using longitude and latitude positions on a Google Map. Competition C has also has multiple intermediate locations called Milestones, which are in path from location A to location B can be explained as a M1 M2 M3 M4. So this competition has six milestones starting from location a, sequential milestones M1, M2, M3, M4 and ending point B. The person who is created this competition is the owner of the competition. The owner of a competition might decide that milestone M3 is not mandatory, because there are some alternative routes, which can be followed in case of traffic, so considering availability of alternative path users might not need to visit M3. So, owner can mention few milestones as optional so, users can skip those if required. Competition C can have one or more time slots, so either competition can be in the morning, afternoon, evening, or in the night.

Competition has some time slots it means the competition is valid for certain amount of time and only in that time user will be evaluated for his driving performance and this time is from 2 hours to 6 hours period. Table 2 explain few terminologies specific to staged competitions. Users who are interested required to subscribe for the competition. On Subscription they will participate automatically in to every instance of that competition. Whenever user is no more interested he/ she can unsubscribe from the competition, after which evaluation will not happen.

Table 2: Staged Competition terminologies

Staged Competition	The Staged Competition is a Competition, which has multiple occurrences (instances) according to time slots & has a specific route. Once user subscribes for certain competition, then every time accordingly to time and location data, framework takes care of user evaluation if user is geographically present for evaluation. Competition is generally open for 2 hour to 6 hours. Competition is generally span around 5 to 20 kilometres. Competition score has a range from 0 to 100.
Timeslots	Time-slot is the period of time, in which competition instance is considered to be open. So, the user will be in evaluated in competition, if and only if time criteria is true. One competition can have many time slots. For example, Morning slot, evening slot, late night slot and even can have overlapping timeslots. One time slot can be a part of different competitions. If timeslot is in competition then in that period competition instance is considered to open by the server.
Milestone	The GPS co-ordinate specified using latitude and longitude on the map acts as a location on route of competition. Milestone has a proximity radius.

Proximity radius	The GPS co-ordinate specified using latitude and longitude is a small geographical area, the vehicle practically cannot visit the exact location, so, proximity radius provides geographical circle around the co-ordinate. So, vehicle inside the proximity radius is considered as visiting actually GPS location. In City areas Proximity radius about 200 meters is used in the testing scenarios. On Highways proximity radius of 300 meters radius is used.
Route	List of milestones, containing start location, intermediate locations and the final location. The Route is ordered list of Milestones, which vehicle should visit one after another. Few of Milestones in competition can be Optional which can be skipped.
Competition Start Point	It is a geographical location, which is the first point in milestone list, visiting this location in valid timeslot ensures user is competing in the competition.
Competition End Point	It is a geographical location, which should be visited to complete the competition, although other criteria's should pass to complete the competition successfully.
Optional Milestones	Owner can specify option milestones in the competition route. It is an integer number. User competing in competition can skip optional milestones, and it does not affect the successful completion of competition.

Table 3 provides an example of staged competition, the competition "Albaro Genova", has the route from "Brignole" to "Via Albaro, 15-53" and has 3 timeslots. First timeslot is morning 10am to 12am in Jan 2018 month, Second timeslot is morning 10am to 12am, on 1st Feb to 5th Feb 2018 and the third timeslot is evening 6pm to 7pm on 1st Feb to 5th Feb 2018. Competition has proximity radios of 300meters, so, if vehicle goes in radius of 300meters in any of location, will be considered to be visiting the location.

Table 3: Example of Staged Competition

Name	Albaro Genova	
Route	Brignole, Corso Buenos Aires 1, Piazza Tommaseo, Via Francesco Pozzo, 15-21 [Option Milestone], Via Albaro, 15-53	
Time-slots	1 Jan 2018 – 31 Jan 2018 (10AM to 12AM)	
	1 Feb 2018 – 5 Feb 2018(10AM to 12AM) (6PM to 7PM)	
Proximity radius	300 meters	
Owner	User2	
Subscribers	User1, User3	
Awards	{ {1: 50 Virtual Coins} {2:30 Virtual Coins} {3:10 Virtual Coins}	

There different new entities and contributors are accommodated inside the framework as a content provider or content user. The specific roles and ideas are explained in table 4. The staged competition is the way of using automatic configurations for driver evaluation which will make the use of evaluation in real time.

Table 4: Supportive elements of Staged Competition

Contributors	Contributor is a Person who design milestone or timeslot or a competition contributes elements in a framework.
Owners	The person who design competition, milestone, and timeslots is the owner of that element, and can edit/delete the element. Other users can only use it without any change.
Competition Subscriber	The user who is interest to compete in particular competition can subscribe for it, and then automatically participation can happen when timeslot and milestone criteria is true.
Invitation	The competition owner can invite users for compete in completion.
Invitation acceptance or rejection	The user who has received an invitation for a competition can either accept or reject it. If user accepts the invitation the user becomes a subscriber of the competition, in other case, user does not.
Subscribing a competition	The user can subscribe to the competition by accepting the invite or my manually searching for a competition and subscribing it.
Award Criteria	Owner decides what minimal expectation to be a winner is, by mentioning championship. Generally owner of the competition can decide depending upon instances and ranks, top ranked users and their awards.

Application	The Applications are criteria of evaluation for example: Green Drive, Safe Drive, and Eco-drive having motivations of different environment friendly driving criteria.
Competition area	It is a location around a size of city where competition geographically takes place
Championship	This is a collection of some fixed number of competition instances (mentioned by competition owner) for which users can be evaluated and competition owner can assign a prize for winners of championship over single competition instance.

In fig 48, Automatic Competition configuration is manager and its submodules are depicted. The Periodic score manager takes care of partial scores which are arriving from the evaluators and keeps track of scores in different time units. For example having 3 scores on 20 seconds is used to get score of 1 min and such 60 scores are used to get hourly score. But the manager has its unique algorithm over just taking average, so, penalty cases will not get dominated by huge number of normal scores. The Timeslot manager is responsible for managing timeslots and competition instances accordingly. The Championship manager hold a collected of competition instances and winners of those. The Invitation manager manages the database related to subscription and invitation for different users for different competitions. Milestone manager is responsible for distance calculation and deciding on if vehicle driver is in specific location. This information helps framework make pass or fail the user for the entry criteria of specific competition. The milestone manager also responsible to check if milestones are getting visited in certain order by users. Timestamp manager works with time related data, it works with timeslots, competition instances and user entry and exit from competition.

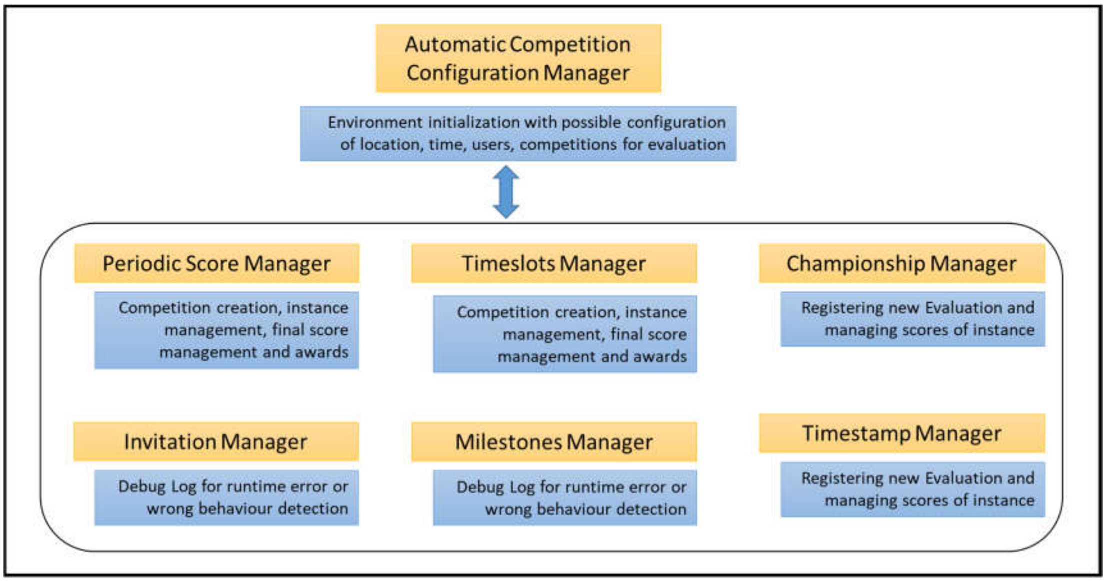
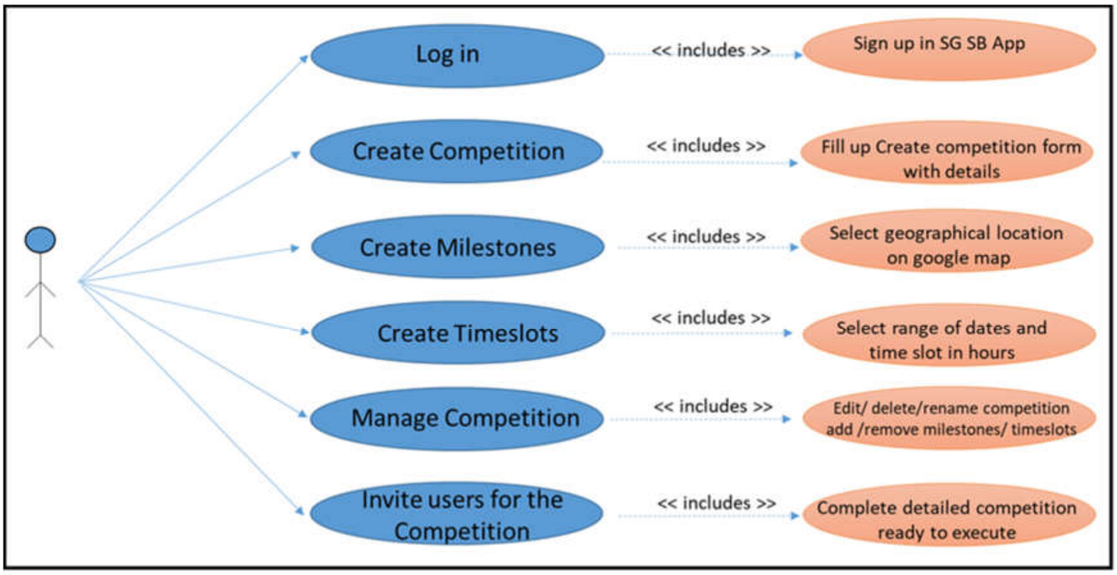
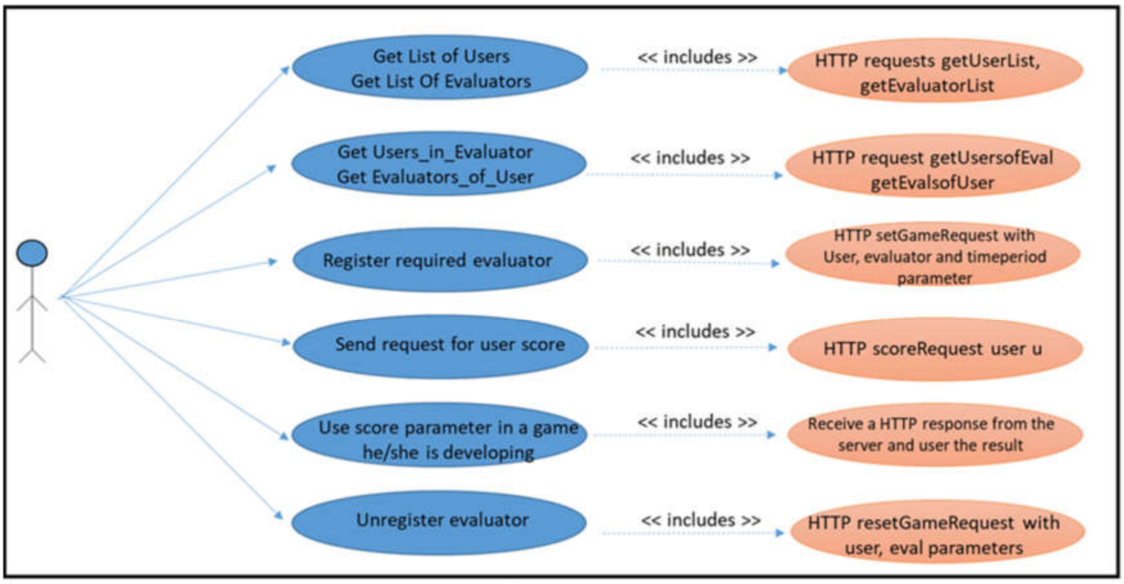


Figure 48: Staged competition server modules and services

As Use case diagram in fig. 49 shows the use case for competition owner, and game designer. The competition owner can create a competition and can select or create timeslots and milestones, then can invite users for the competition. The game designer need to sign up to the system and then by few request calls he/she becomes aware of evaluator which is perfect suited for his/her games and with that knowledge using Game API possible to request the score on constant intervals.



(a)



(b)

Figure 49: Use case diagrams: (a) Competition Owner use case (b) Game designer use case

This Automatic configuration model has 3 main elements: Cloud with RESTful APIs, Competition Manager Smart-Phone Application & SG-CB application

Competition Participation:

User can see the competition open using SG-CB application or Competition manager. User need to subscribe the competition. User can get the details of the competition using either Competition manager or SG-CB application. Once user subscribe competition C, he/she can participate into competition by being a Starting Point is location pointed by Longitude and Latitude and Proximity is in 30 meters. Once driver is in to competition, only aim would be to drive vehicle safely, fuel-efficiently and environment friendly. Fig. 50, show a snapshot of what user cab browser about the competition.

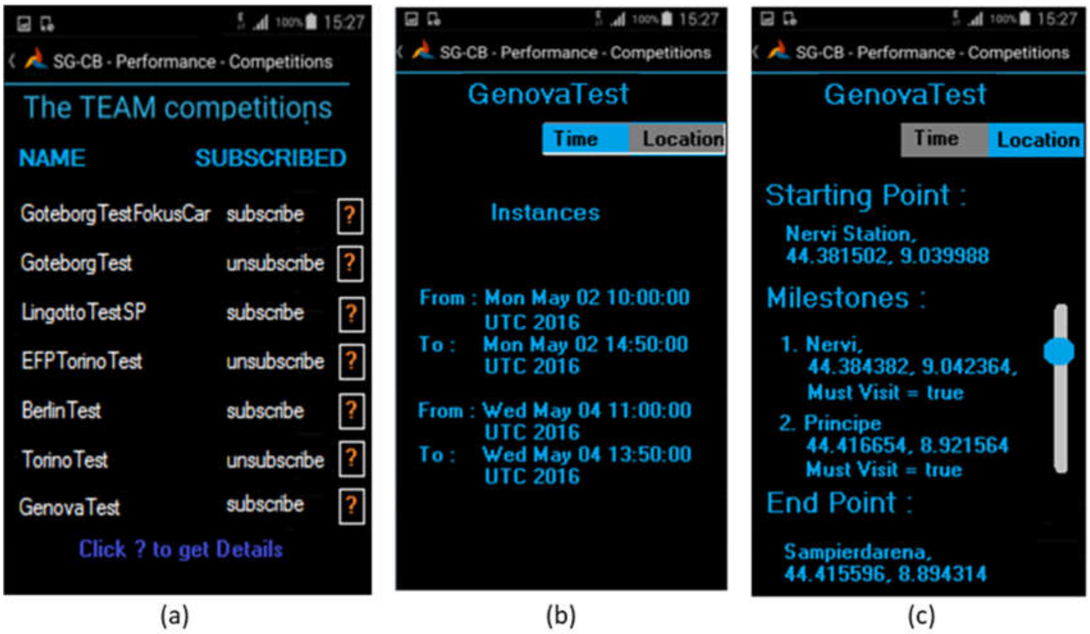


Figure 50: Staged competition details and Subscription

8.3 Staged Competition Manager (Smart Phone Application)

This is a smart phone application to manage the automatic configuration for vehicle driver performance. This application allows different users to create competitions, add milestones and timeslots, allot prizes and invite users for competing to win. The targeted users of the application are HR Team of Company, or any organization who wish to sponsor for the Green driving in private or in public. The Competition manger is extension tool of SG-CB and have got developed specially for Automatic Configuration of the competitions. So few operations and information retrieval is possible using any of the application.

User need to follow the route in order to visit the mentioned milestones on the route. User can see his performance in SG-CB Android Application Continuously, can observe up and downs in score as per his performance as well as can see his/her performance against others. When Driver reaches to the finish point radius of Longitude and Latitude, Competition finishes. Driver Rank is still subject to vary until competition time finishes, and no other users are in competition.

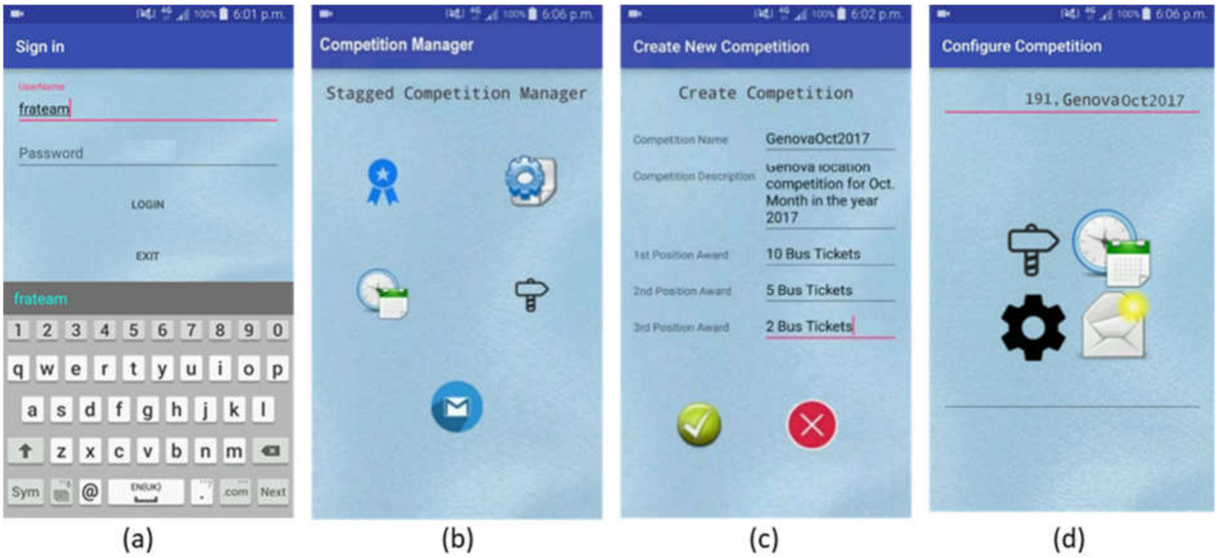


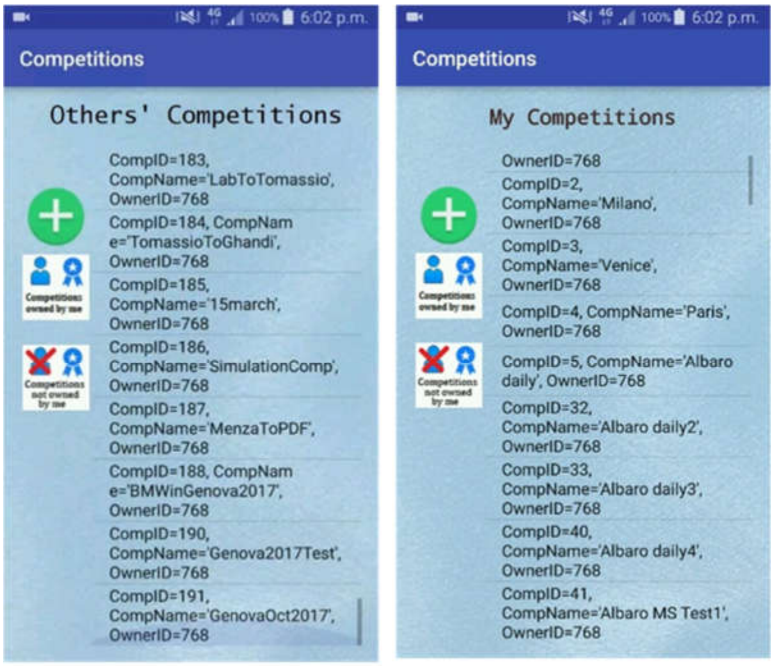
Figure 51: Using Automatic Competition Configuration Tool for Staged Competition creation

Any user registered in SG-SB, (Serious Games and Community Building) Application can user Competition Manager Application without any Registration. For any new user registration SG-SB application has to be used first. Competition Manager does not allow registration of new user. So, it leverages the SG-SB user registrations. As anyway without being part of SG-SB, Automatic Configuration does not have any use. User of this tool can be either competition owner, milestone owner, timeslot owner, vehicle driver who want to user evaluation and gamification and earn prizes by driving green. When user logs in (refer fig. 51 (a)) to the Competition Manager Application, user can perform different operations: (refer fig. 51(b))

1. Can create competition;
2. Can create or remove timeslots and milestones;
3. Can check his/her own invitations for other's competitions.

Any user of the system can create a competition. User need to provide few basic information about the competition. Then User can add milestones and timeslots successively after the creation. Snapshot shows the sample of Creation of Competition "GenovaOct2017" (refer Fig. 51(c)). User who creates this, being an owner of the competition wish to offer prizes for 3 top ranks. After this basic details only competition can be created. Once competition is created competition owner can add timeslot and milestones in to it (refer fig. 51 (d)). Once competition owner creates any competition, subsequently can add Timeslots and

Milestones to it. As well as can change basic data related to competition, which includes name, descriptions, awards. Competition owner can then user Competition Invitation Button for Navigating to “Competition Invitations” where Competition owner can invite user for the competition and also can check the status of his/her earlier requests. If competition owner selects the competition and configure competition for milestones, then in Milestone page Competition specific buttons appear: “Milestones in Competition” and “Milestones not in Competition”. Milestones module exposes information about Milestone entries in the database. User can check Milestones created by him/her, by clicking on “Milestones created by me”.



(a) (b)

Figure 52: Owned competitions and other users' competitions

Using Competition Manager Module user can check competitions created by other users (refer Fig. 52 (a)) and by him/her (refer fig. 52 (b)). Being an owner of these competitions user can perform some changes in the competition if required. Which includes adding or removing timeslots or milestones, inviting users for the competitions, changing prizes and editing the competition description. User can check competitions created by other users but can’t edit or remove them.

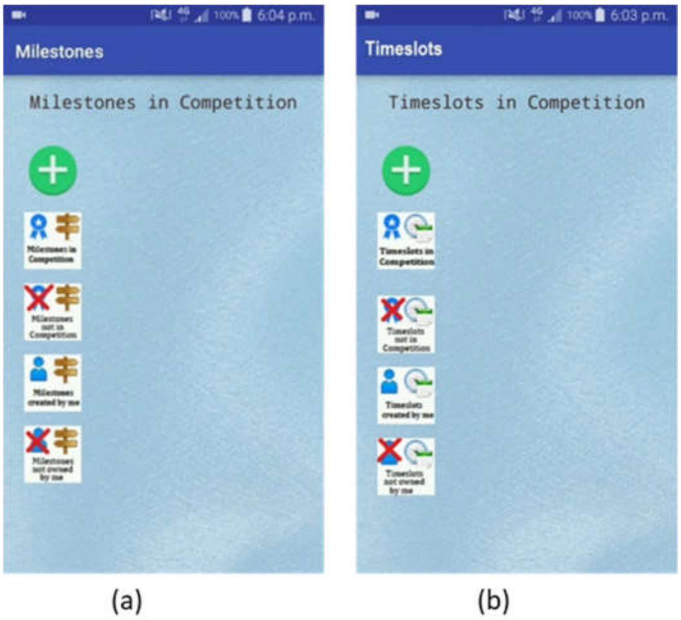


Figure 53: New competition has no Timeslots and Milestones

Milestones:

Competition owner can add the Milestones to the competition using Milestones module. For new competition Milestone list and time slot list are empty (refer fig. 53). Owner has to select the Milestones either from list of his own Milestones, or global Milestones or even can create new and add in the competition on the go. Competition owner also can delete few milestones. Competition owner can reshuffle the milestones if required.

Timeslots:

Owner has to select the timeslot either from list of his own timeslots, global timeslots or even can create new by clicking on create Timeslot button (Green +) and add in the competition on the go. Once this timeslots gets added to the competition, they work as a start and stop clock for each competition instance. Using Timeslots, the competition manager can add timeslots to the competition.

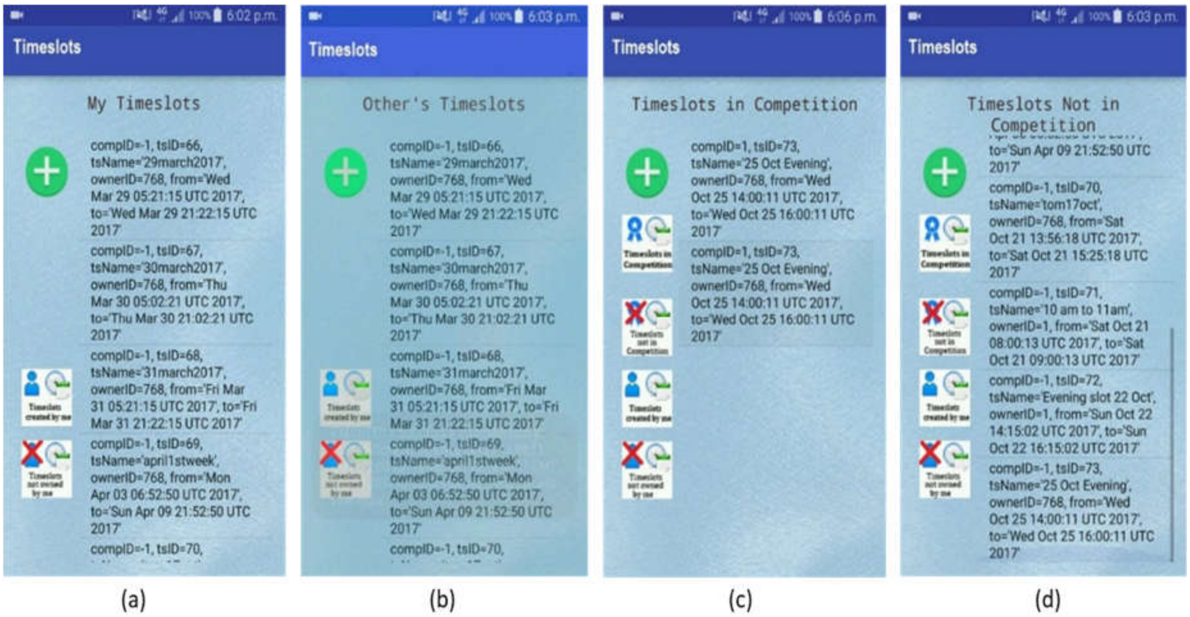


Figure 54: (a) User's Timeslots (b) Other users' Timeslots (c) Timeslots in Selected Competition (d) Timeslots not in Selected Competition

Competition owner can add Timeslots to the competition using Timeslot module (refer fig. 54).

1. Competition owner can check the timeslots which were created by his/her. (Refer fig. 54 (a))
2. Competition owner can check the timeslots which were created by other users. (Refer fig. 54 (b))
3. Competition owner can check Timeslot in Competition and can remove them by tapping on them. (Refer fig. 54 (c))
4. Competition owner can check Timeslot which are not in competition and can then add them in Competition by tapping on them. (Refer fig. 54 (d))
5. Competition owner can create new Timeslot. (Refer Fig. 55)

Once user selects range of the days, (refer fig. 55 a, b) and then select time for each day (refer fig. c, d, e, f) which should be of 2 hour to 6 hours. Then user can create the timeslots by providing a name (refer fig. 55 (c)). On creating user can see this new timeslot added in “My Timeslots”. If this timeslots gets added to the competition then as per server logic, every day in those date range, the timeslot fixed will be considered as open instance for the competition.

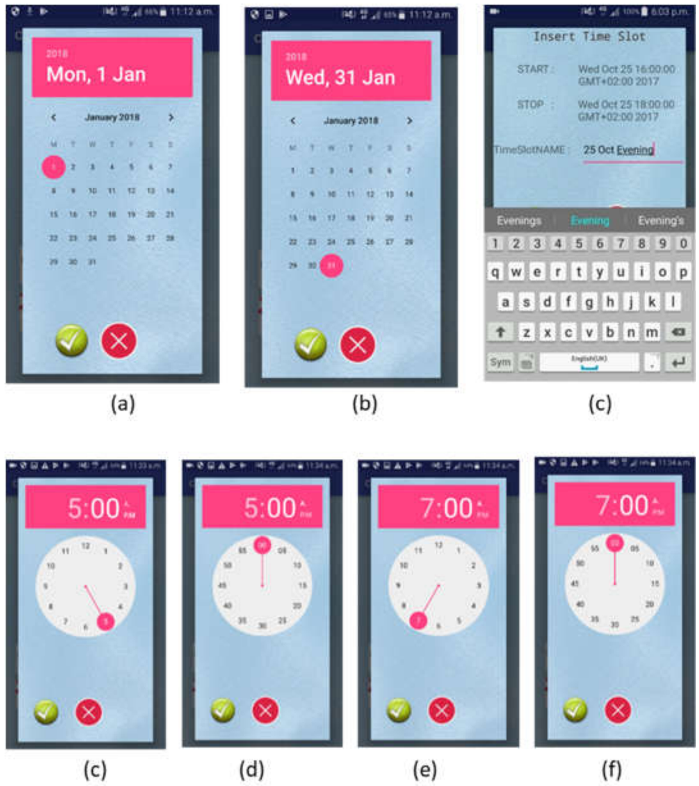


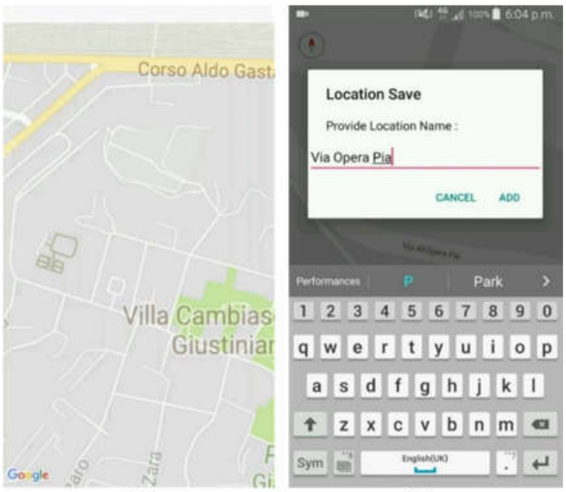
Figure 55: Timeslot Creation - (a) Select Start Date (b) select end date (d, e) select Time when everyday competition should start at, (f, g) select time when competition should stop for that day, (c) name the Timeslot

Figure 56: Milestones - (a) user's Milestones (b) Other users' Milestones (c) Milestones in selected Competition (d) Milestones not in selected Competition

Competition owner can add Milestones to the competition using Timeslot module.

1. Competition owner can check Milestones which are not in competition and can then add them in Competition by tapping on them. (refer fig. 56 (d))
2. Competition owner can check the Milestones which were created by his/her. (refer fig. 56 (a))
3. Competition owner can check the Milestones which were created by other users. (refer fig. 56 (b))
4. Competition owner can shuffle Milestones in Competition to make sequential route on the map and can remove them by tapping on them. (refer fig. 56 (c))
5. Competition owner can create new milestone. (refer fig. 56 (c))

Milestones in order can form a route for a competition. First milestone is starting location of the competition and last milestone is the ending location of the competition.



(a) (b)

Figure 57: Milestone Creation: (a) Tap on the location using Application given google map to create that location as new milestone (b) provide a name for the milestone

To create a milestone user need to tap on Green + button Create Milestone. Then user has to locate and tap on location on google map (refer fig. 57 (a)). It prompts the user for milestone name. Milestone gets inserted in the server database using RESTful API (refer fig. 57 (b).

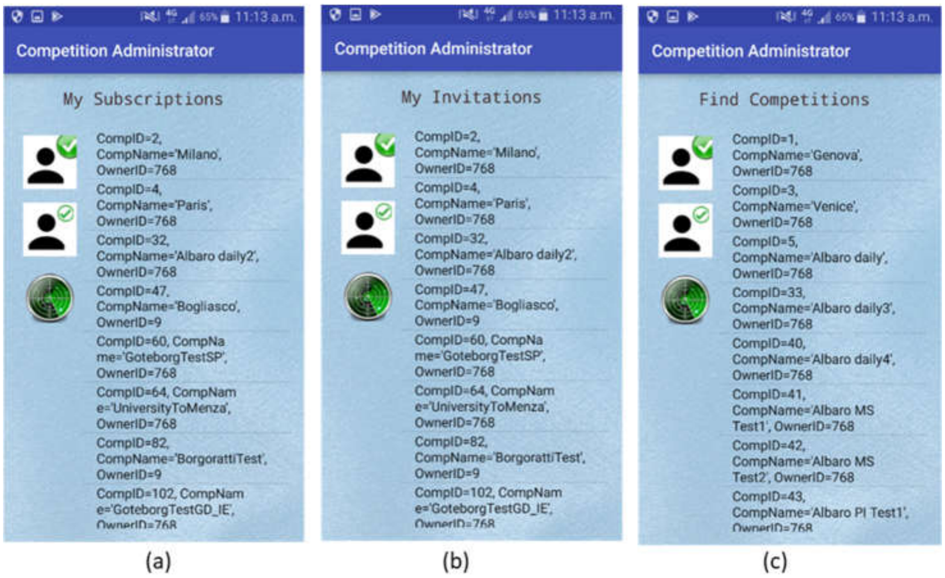


Figure 58: User's Invitations - (a) User's subscribed competitions (b) New invitations sent by competition owners to user for subscribing competition (c) User can subscribe competition by searching in global list

Invitations module allows social collaboration between different users. User can check his invitations for competition (refer fig. 58 (b)), sent by different competition owners. User can check the competition details and can take decision whether to accept it or reject it. If user accept the competition invitation then automatically user subscribes to the competition. User check his/her subscriptions (refer fig 58 (a)), and can find competition and subscribe them (refer fig. 58 (c)).

Figure 59: Competition Invitation: This is used by Competition owner for inviting other users (a) Users who are already subscribed to the competition selected (b) Invite more users to participate in the selected competition (c) List of already Invited users

Competition owner can use Competition Invitations page to invite user for the competition (refer fig. 59 (b)). Competition owner can check subscribed user to his/ her competition (refer fig. 59 (a)). Competition owner can invite more users from global list of users in application (refer fig. 59 (c)). Competition owner can check already invited users. These 3 lists are exclusive. So for any competition any user can be in either of list. User can also check other's milestones by clicking on "Milestones not owned by me".

9. Experiments

From the observations, it can be noted that the four evaluators have different grading patterns for various types of signals, users and driving styles. The Linear distance has a penalizing scheme based on segments with standard flow of virtual coins and dynamic sliding window's evaluation has a penalizing modality based on the harsh events exhibited by the user. The sample set is a base for K-NN, the construction of sample set would involve the keen analysis of the data pattern. Dynamic sliding window requires a continuous signal pattern with gradual rise and fall to track the events accordingly. These four evaluation approaches have been designed to provide a viable solution to the various needs of the user and most importantly for the betterment of the driving skills. Also by having these dimensions in evaluation mechanisms can facilitate the process of model adaptation, because model adaptation is one common problem in modelling the driver behaviour. I hypothesize, the methodology of comparing user performance analysis with the performance of peers for deriving the detailed analysis of user calibre.

The first part of the evaluation involves the absolute comparison, where the user scores are received from the vehicle simulation Unit and are tabulated on the grading scale for the performance metrics (Good, Average and Bad).The test scenario consisted of samples collected for 5 minutes with the update frequency on the timestamp of 10 seconds. These values of the scores were absolute and ranged based on the evaluated user performance in Vehicle simulation unit. On other hand, the Fluid traffic has the evaluation pattern based on speed signals, where the comparison of absolute performance is displayed on Fig 5.

Another significant aspect of my approach is the social comparison, where the individual user performance is analysed with the average of all the users on the link. The average values of all the users in a various links (Geo referenced zones) are tabulated in the Aggregation server and the user performance on a particular link is compared with the average values derived from the Aggregation Server to estimate the final outcome. Fig.6. represents the social comparison results of Green Drive on the average scale and the percentage of the performance overview.

The average scale denotes the difference of the values calculated from the Aggregation server and vehicle simulation unit for extraction of the social comparison results. From the tabulated data of green drive, it can be noted that the social comparison of user seems nominal with certain amount of coarse pattern.

Whereas, the fluid traffic holds maximum amount of inadequate performance on the grading scale. As the results of the analysis are represented spontaneously on Google Maps, which would also provide the user an insight about the locations where the driving pattern can be enhanced. The social comparison also stands as a hidden factor that could motivate the driver to maintain smooth driving behaviour. Therefore, this method provides an in-depth analysis of user performance on two scales (absolute and social comparison) and this can be deployed in real-time for creating a qualitative grading analysis of user performance.

I have conducted simulations as well as On-Site Real-Time Test for testing the framework and evaluation stability for 3 car models. Cars had different user Ids and competed against each other, under the evaluation criteria of Fuel, Eco-Friendly and Green-driving. The car models which support CAN bus and OSGi Environment, in-car evaluation was used and for other car models In-Application evaluation was used. The competition were designed for Trento-Italy; Turin-Italy, Genova-Italy, Goteborg-Sweden, Berlin-Germany.

9.1 Simulations:

This section explain method of simulation. At the starting phase of the research activity some vehicle signals were available in log files. I have made a simulator for creating driving patterns by using one original log file. This methodology by observing histogram of a signal it is possible to see the distribution of signal values in particular period of time. As a histogram is a representation of the distribution of numerical data and it is an estimate of the probability distribution of a continuous variable. The different between two subsequent samples in that period gives the possible range of value change for any signal. The histogram of this values correlated with signal sample value at that instance gives the understanding to possible value change in signal value at any stage.

9.1.1 Implementation Overview

The system core manages the driver performance evaluation by unifying four architectures together (see Fig. 60), here the evaluation is done based on the relative plot of the scores with the average performances of the peers.

The system core comprises of four architectures:

Vehicle Simulation Unit

- Driver Performance Evaluator
- Aggregation server
- Live User performance by visual representation

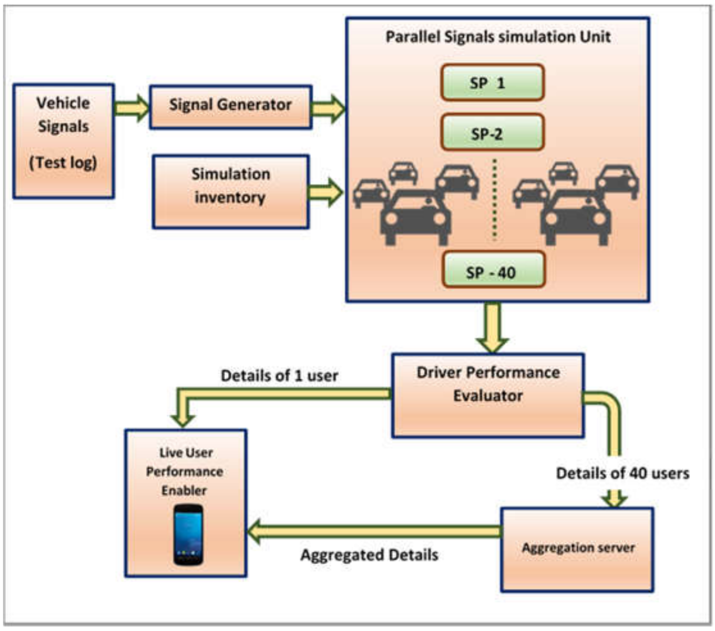


Figure 60: Simulated signals for 40 users and one specific user gets evaluated against average of other users using Aggregation server and then performance enabler shows the status of user visually on SG-SB Application

9.1.2 Aggregation Server

The Aggregation server receives the signals of 40 vehicles from the Vehicle simulation unit and stores the entire details of the vehicle signals, Geo-references and users associated with it. The key element of Aggregation server is the computation of average performances of 40 users, where the latest and historic user performances are tabulated based on the geographic links. Aggregation server responds to the live user performance enabler module for the comparison of individual performance of the user with the average performance of all the users that were recorded on the links.

Apart from computation of user performance, the visualization of the results on Google maps is another feature associated with this system. In real-world recordings of Geo-references there can be a deviation from the actual position and this might result in a drastic change when the coordinates are displayed on Google Maps. To resolve the errors associated with variations in Geo-references, our research team in lab contributed in it by used Map-Matching algorithm [27] (The map-matching API "GeoToolBox" [27]) to integrate the position data with Spatial Road Network data to identify the correct link and coordinates on which the vehicle is travelling [28]. The vehicle coordinates are sent from the route repository of GPS locations to the Map-matching module for the correction, the Map-matching module is housed in OSGi framework. The Map-matching module relies on a Geographic database generated from the OpenStreetMaps files.

OpenStreetMap data describing the road network is preprocessed and converted to PostGis. This results in a line graph of the road network including turn restrictions. Every road is represented by set of links (Unique identifier), therefore by querying vehicle coordinates, possible to retrieve the corresponding road link from the database. Vehicle simulation unit exploits Map-matching module to fetch the entire details of Geo-references and forwards it to the Aggregation server and later these details are used by Live User Performance Enabler unit to plot the road links on Google Maps.

9.1.3 Driver Performance Evaluator:

Parallel simulation unit sends signals to Driver performance evaluator. To evaluate the signals, I developed certain algorithms (Linear distances, K-Nearest neighbours and Dynamic sliding Window) based on various criterion. For this simulation environment, I have used Linear distances to estimate the vehicle signals, in linear distances approach the signals are segregated into harsh and smooth patterns using the slope-intercept form, in which the harsh signals are penalized and smooth ones are rewarded. The signals such as acceleration, brake, RPM and speed are evaluated using Linear Distances. The evaluation is done on the basis of green drive and fluid traffic, where green drive comprises of the evaluation pattern based on Brake, RPM and acceleration signals of the vehicles and fluid traffic estimates the speed signals based on the specified criterion in Linear Distances.

Post signal evaluation, the scores and vehicle details of 40 users are forwarded to the Aggregation server for the computation and only one user score is forwarded to the Live User Performance enabler unit. Later the score of this individual user is compared with the scores of 40 users for deriving the overall performance.

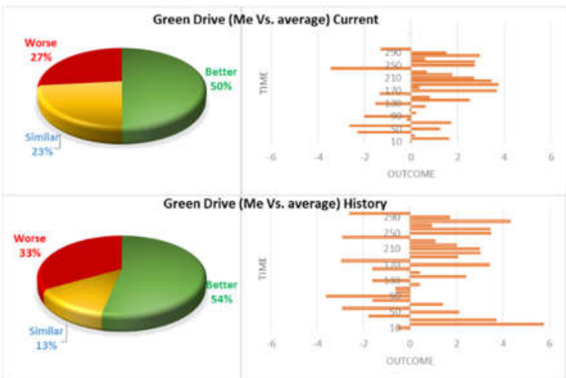


Figure 61: Results of Simulations of 1 user against 40 users' average performance

9.1.4 Vehicle Simulation Unit:

The simulation unit acts as the input part, where the vehicle signals of 40 vehicles are generated over here for this entire test scenario. The source of replication is from the real log file which comprises of vehicle signals recorded by CRF Trento, Italy [26]. Fig.60 comprises of the control flow involved in vehicle simulation unit, the first block (Vehicle signals) holds the test log file from which the signals are generated for the simulation.

The signal generator unit forms the data structure for the signals that flow in and simulation inventory is comprised of certain configuration files associated for the parallel simulation. Simulation inventory handles the logical signal generation from the real signal and maintains the course of the replicated signals to match with the source signal. The 40 vehicles are associated to 40 users and the details of 40 users and the signal mapping to concerned users are done in parallel simulation unit (SP-1 corresponds to signal pack 1 and it goes on till SP-40, as displayed on Fig.60).

The Serious Games and Community Building Application presents the driver evaluation information numerically, statistically and graphically. The SG-SB application sends HTTP Request to the server regarding the data of user who has logged in to the system. Whenever new user want to be a part of the system, he/she is required to sign up on Telecom Italia site for under TEAM project. Once user has his/her own account and password, user can install the SG-CB application and log-in. The figure shows the sign up and log in pages of SG-CB.

9.2 Real-Time On-Site Tests

9.2.1 Test Site description 1 Goteborg, Sweden

By Volvo Group Trucks Technology (GTT) under TEAM IP 7

With Fraunhofer Institute for Open Communication Systems FOKUS

I have participated in field test in ASTA (Active Safety Test Area) ZERO test track in Gothenburg, Sweden. BMW sedan and Mercedes-Benz (s-class) were used for the test. I had created two user accounts in serious gaming android application to understand the performance outcomes of two different users (User - 1 and User - 2). Users monitored for harsh driving events (event analysis), while in a competition. In following figures (Fig. 9 and Fig. 10), the event analysis reports for two users are displayed. Event analysis gets generated once the competition is closed and the events are geo-referenced and time-stamped when they are captured. This facility enables to display events in various perspectives such as map view, summary view, and diary view. Map view represents the events on Google maps with a symbol denoting the signal type

(RPM, acceleration or brake) and colour for the intensity level of the signal(yellow for medium and red for harsh).

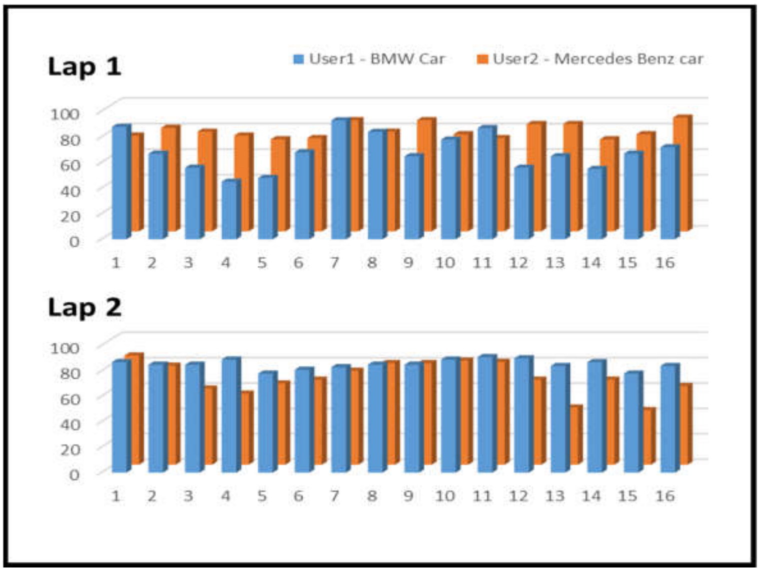


Figure 62: User 1 and User 2 performances in 2 laps

The fig. 62, shows scores of every 20 seconds for both the vehicles. In lap 1, the BMW car driver has driven the car aggressively and Mercedes Benz car driver has driven smoothly. In lap 2, the BMW car driver has driver smoothly and Mercedes Benz car driver had driven with harsh manoeuvres. Fig. 63 shows the good driving lap of BMW car driver and fig. 64 shows bad driving lap of BMW car driver.

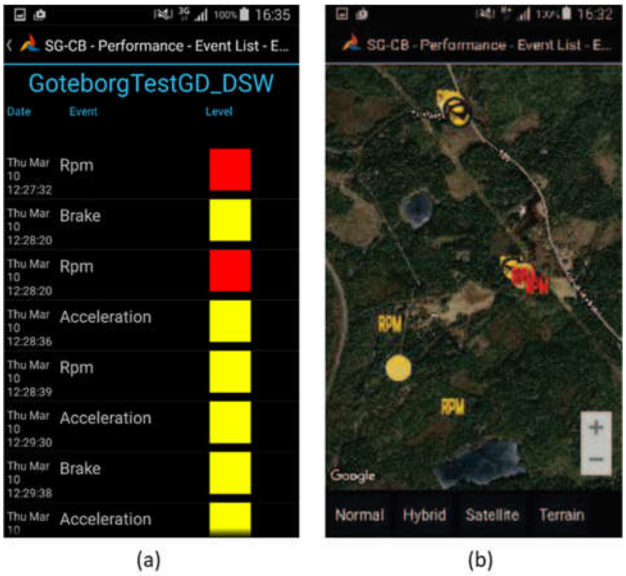


Figure 63: Goteborg Events - good driving lap – BMW car

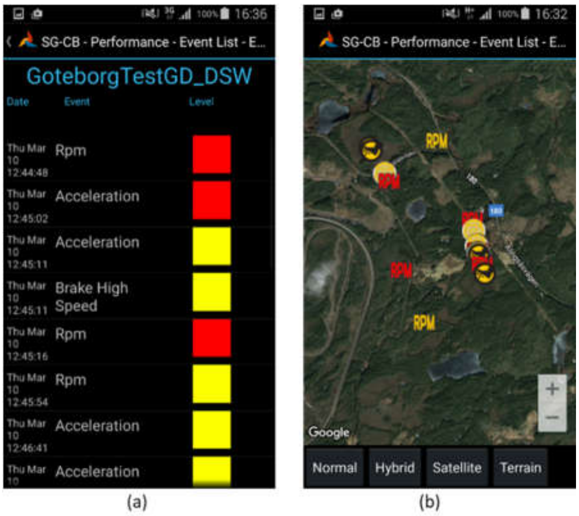
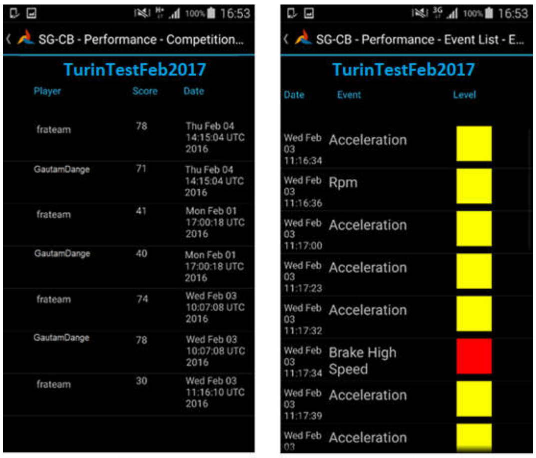


Figure 64: Goteborg Events: bad driving lap – BMW car

9.2.2 Test Site description 2 Turin, Italy Eco Challenge 2017, Feb 2016

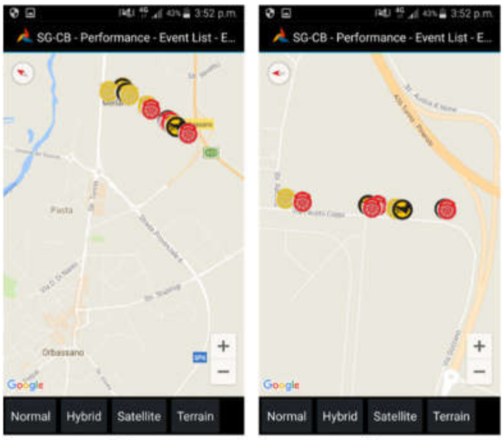
By Centro Ricerche FIAT under TEAM IP 7

I participated in TEAM project hosted event Eco challenge in Turin, Italy in Feb. 2016. There this test has got conducted. The 2 FIAT 500 cars were used in the tests. That time framework was not ready and I used xml configuration files to set user names in to vehicle OSGi environment. In first week of Feb. 2016, multiple days tests were conducted. The evaluation got tests and few gamifications leveraging this framework also got tested. Multiple laps were conducted for the Green drive evaluation and alternatively cars drove harsh and green to observe the variations in score and to visualize events on the road. The fig. 65 (a) shows the



(a) (b)

Figure 65: Turin Eco Challenge - Test Outcome (a) Scores (b) events list



(a) (b)

Figure 66: Turin Eco Challenge - Test outcome events (a) car 1 (b) car 2

9.2.3 Test Site description 3 Trento, Italy [Remote Test, from Genova] By Centro Ricerche FIAT under TEAM IP 7

The test run was conducted by Centro Ricerche Fiat (CRF) and the test site was located around the CRF office in Trento, Italy (refer fig. 65) and the test site comprised of various road segments such as urban, suburban and the mixture of both. The test site was divided into four major zones such as Tangenziale, Viale Verona, Misto and Via Nationale and expands around 13 Kilometres, with approximate completion time of the entire run around 28-30 Minutes. Map of the test site in Trento, Italy with locations comprising of urban and sub urban zones. The red route highlighted on the map is the suburban zone (Tangenziale) and the green route is of urban zone (Viale Verona). The blue and purple routes are the mixture of urban and suburban zones.

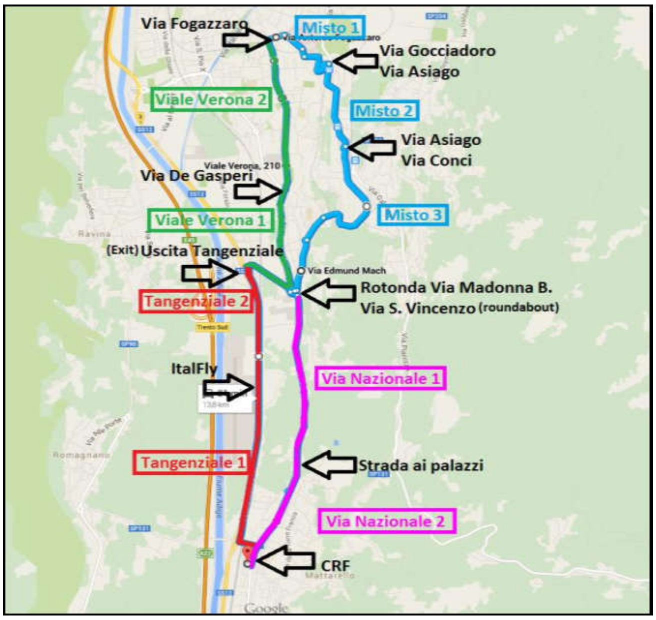


Figure 67: Trento Test Site

9.2.4 On-Site Test with Smart-phone based (In-App) Evaluation:

By Volvo Group Trucks Technology (GTT) under TEAM IP 7

With Fraunhofer Institute for Open Communication Systems FOKUS

I have tested the entire control flow of the system, in ASTA ZERO (Active Safety Test Area) test track in Gothenburg, Sweden on 10 March 2016. For the test, BMW sedan and a Samsung Galaxy s5 smartphone for smart phone evaluation were used and the smartphone was mounted on the dashboard.

The test run comprised of two laps on the test track, out of which the first drive (Lap 1) comprised of bad driving behaviour with frequent harsh driving events and the second lap comprised of optimal driving performance with a minimal amount of harsh patterns. Each lap lasted approximately for 10 minutes around the same locality. The main consideration behind these two types of driving style is to compare and estimate the quality of driving and test the functionality of the game logics implemented in this framework. I extracted the vehicle signals and the evaluation results from green drive evaluators (the Instantaneous and smartphone-based evaluations).

9.2.5 Test Site description 4 Genova, Italy, [Smart Phone Evaluator only]

By Researchers,

Department of Naval, Electrical, Electronic and Telecommunications Engineering,

University of Genova

In Genova City, we conducted few Tests with users for Smartphone evaluation and few researcher of lab tested their gamifications using this framework. The Foce, Genova, Italy area was selected for the test. Fig. 68 shows the results of the Genova test on different dates, we have conducted multiple tests not only for checking evaluation, but for checking framework, automatic configuration of competition and few gamifications which are developed by research team in university of Genova, DITEN lab colleagues. Fig 68 (a) shows scores of different laps, fig. 68(b) shows the events on the map and 68(c) shows the list of events.

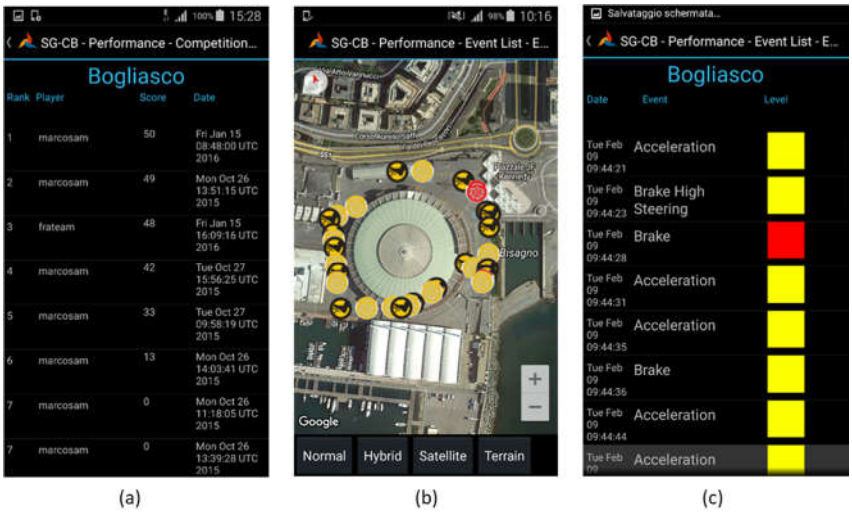


Figure 68: Genova Tests

10 Conclusion Limitations and Future work

As a consolidation, I have implemented a framework with a set of algorithms including the significant machine learning approaches to evaluate the driver performance evaluation based on various vehicle signals acquired in test runs conducted by Centro Ricerche Fiat (CRF), I Trento and Turin, Italy and by Volvo in Goteborg, Sweden. I have designed a framework, where Driver will automatically participate in evaluations without configurations, and thus the evaluation algorithms can be used in Real-time. Which will also allow users to create competitions and invite other users to take part in the competition.

Although with experimentation we could confirm that the evaluators are providing sufficient information to distinguish between harsh, smooth driving and green driving. Few limitations of this approach are its dependency on gamifications which are already present in my lab and to be built. The games built using this framework should be able to give driver enough entertaining and engaging experience so the evaluation can be used continuously. The users tests would need to be conducted for those games on regular basis to understand if users are getting motivated with those applications, if user can see some performance improvement and if user feel more aware of this driving. But this needs hardware support from car manufacturers which is in fact missing at present. The immediate gamification of evaluation happens with few real time games, and it would be game designers responsibility about caring not to contribute in driver distraction by his/her games. The framework allows addition and removal of evaluators and games and framework expect all evaluators are permanent. There is no notification mechanism implemented which can inform game designer if evaluator is sending data or if it have removed from the framework and game designer requires to change evaluator in the API calls. So, as of now, this framework expects game designers to be aware of availability and correctness of the evaluator.

Evaluation metrics such as event-based, relativity mapping and segmenting, I have attained a viable solution to track the driver behaviour on all occasions and driving standards. This methodology would be a stable approach as it is a collection of model adaptive tools and the tests were carried out on a real-world scenario. This approach provides the wider spectrum of the user performance details for Green drive and Fluid traffic corresponding to latest and historic observations. The methods used in the simulation environment and then transformed to the real world platform by discarding the vehicle simulation unit from the architecture and direct transmission of the vehicle signal evaluation to the server. The individual user can see the live performance as well as can fetch the performance analysis report directly on the smartphone application. The main idea behind the presented concept is the creation of an ecosystem for connected, collaborative and green mobility. While the main focus up to now is on driving, different means of transport are considered as well. The ecosystem is based on rewarding proper user behaviour through virtual and/or real-world incentives. Attention must be paid in the management of the system, that the included services are coherent with the goal of the system. The ecosystem looks particularly suited to the promotion of new mobility services. Examples of incentives could be discounts from public authorities, transport companies and insurances that could attract more users and build communities. Corporate communities are useful for companies to stay in constant contact with their customers and get data to improve their products and services. While the system has been developed for mobility-based games, the infrastructure is general and may be used in a variety of domains.

The results from the test drive comprised of good and bad driver behaviours, emphasize on the fact that the gaming aspect gives a bigger space for the users to understand the driving context and enable them to develop their driving standards, especially when the performance is low. I consider the major importance of this framework is in bringing out the qualities of the driver, by creating an awareness of one's own driving skills with a detailed report of the drive. From the extracted results of test run, I have noted certain factors of our system such as: In real-world scenarios, the gaming methodology would induce a competitive viewpoint among the road users and encourages the drivers to adapt optimal driving traits. The HMI comprised of the detailed representation of the game logics will impact the driver behaviour to a greater extent, as it provides a broader analysis of performance aspects like representation of scores, acquired virtual coins, and display of harsh driving events on Google. Thus, the potential of serious games can be developed to captivate the road users for exhibiting better driving qualities and the pervasiveness of smartphones can reinforce the task of conveying the information in an efficient way. These factors can keep users aware and thus can help in maintaining the safe environment and can support the community of the road users by different information and awards. The game approaches provide a performance visualization and gamification that would enable the users to visualize driving behaviour in different forms which includes virtual coins, statistics of performance, events on map and on the game screen. This mechanism would also induce a game based learning traits, as my focus was on to reflect the driving performance directly on visual.

My work is also accomplished the motive of reducing the configurational settings for establishing the Competition for each driver, and seamlessly users are able to participate in to competition once they have either Smartphone based or in-car evaluator. Henceforth, the process of performance gamification will provide the users with a competitive self-gaming experience and also promotes the collaborative green mobility. In stage competitions, the users can enrol in a competition, and then automatically depending upon location and time, Automatic configuration framework takes care of the tasks like following a specific route and attaining few milestones associated with that route. Users can invite friends to take part in the competition. From the survey [57] [58], it was evident that most of the issues concerning road safety are associated with driver behaviour. I used the serious game concept to formulate various game approaches (competitive and immediate feedback APIs) to enhance driver performance. These game approaches provide feedback to users on a timely basis, and this feedback will account a lot in inducing the knowledge about the performance.

I have conducted field tests to understand the implications of gaming in a real-time scenario, where research team in my laboratory have developed few games leveraging these results. The test results, show variations in performances with two users and this variation enabled us to understand the response of this framework towards different users. The responses from field tests have provided me with a good understanding of the factors concerning tool configuration, safety, and usability. New game designer can use this framework for developing serious games and without being aware of evaluations. As well as, new evaluators can also be developed and they can subscribe to framework for score storage and visual representations. Moreover those evaluation results can be used by game designers. This ideology not only restricts to transportation but even different evaluators can leverage the framework. This creates new opportunity in development of games and evaluation, as in the field of serious games, game developer may not completely aware of the fundamentals of evaluation. This framework shows the future scope where, this limitation can be removed in few games where evaluation affects the games but game interaction goes not effect or affect evaluation.

The RESTful API based server architecture allows transfer of small event and score signals with details of User, Competition, location from car/smartphone to sever with minimal data usage. The data usages need for this framework are minimal and can be adapted easily. Due to size of HTTP Post message is very small and in framework it is in kilobytes. These messages are able to get transmitted in couple of seconds, which is sufficient enough for serious games. The network issues are resolved by updating local file with results and when network become available evaluators send those to server without much of hassle. As time value is allotted to each resulting evaluation, the results tracing is easy on server.

Many practical usage of this framework are possible in transportation scenarios and list includes City Taxi service, City Bus Server, Vehicle registration office. In case of Vehicle registration office, the Scores of the drivers can be mapped to a discount formula, where drivers with good scores can take the advantages of registration fee discount. This also encourages more drivers to sign up for the system. In case of City Taxi service, Taxi driver can get more benefits and from Taxi company. In case of Bus Services, the office can have more awards for efficient drivers.

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