Telemetry-based Optimisation for User Training in Racing Simulators

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Abstract

¡To be revisited after the entire document is finalised as to include a sentence about each chapter.¿

Serious games are known to be an effective tool for improving learning. Recent years seeing an increase in a wide area of applications that flooding various markets. This project will be looking into utilising off the shelf hardware and software to simulate a race car being driven on track. On top of which a software will be developed to interpret user driving patterns and providing auditory feedback explaining what can be improved. The objective is to explore if there is any viability in using a serious game to help drivers improve their skills on a race track. After carrying out user studies and collecting data, data analysis is carried out from which conclusions are drawn regarding any improvements in the users' skills after using the system.

1 Acknowledgements

Luke for racing rig

Keith and Sandro

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3 Introduction

The aims and goals of the project. Any non-aims of the project (e.g. in a purely theoretical project, the development of an artifact would not necessarily be an aim). The approach used. Any assumptions. A high level description of the project.

The gamification of areas of activity such as marketing, problem solving and education [15] has validated the use of serious games beyond their initial military use in training strategic skills [6]. Serious games simulate real-world processes designed for the purpose of solving a problem, making their main purpose that of training or educating users. Their popularity has been steadily increasing, as has their adoption, with military [6] and emergency service providers (e.g. firefighters [15]) employing them to train for specific scenarios that might be encountered on the respective jobs. Motorsports cover a broad range of activities and vehicles, and as with all major forms of sporting activities, require training and dedication, with a pedagogic aspect arising in rote learning and mentoring by experts. The arenas in which motorsport events take places are called circuits; there is a large selection of the latter, ranging from purposely built race tracks to public roads to natural formations such as hills and quarries. There is also a diverse selection of vehicles that take part in motorsports, with the greatest demarcation existing between motorbikes and cars. The focus of this dissertation is that of unifying serious games and motorsport racing; specifically, it will try to show whether a serious game is a powerful enough pedagogical tool that can be used to tangibly improve the performance of race drivers. The scope of the project is limited to four-wheeled cars racing on purposely-built confined circuits with a smooth tarmac surface.

3.1 Motivation

The training process for race drivers has stabilised during the last decade, with rote learning playing a very important part. Starting at an early age, a driver would compete in lower leagues, such as go karting, and undergo training that is mostly founded on trial and error. A mentor, or coach, would correct obvious mistakes and suggest ways for improvement based on experiential knowledge and related literature. The extensive hours of practice serve to hone the skills of a driver and help in the acquisition of the same experiential knowledge of the mentor. Such learning methodology is very resource consuming in that it requires both time and money; often it is geographically-constrained as well, where no suitable training track is available in the locality of the driver. Although simulators, such as those employed by professional racing teams, have helped mitigating traveling and car setup times, they are inadequate for use in more amateurish environments due to cost and logistical problems: setting up such a simulator requires adequate space seldom available to everyone. Democratising the learning process such that proper car control and racing techniques can be mastered by a larger demographic an important motivation behind this work.

3.2 Why the problem is non-trivial

The problem at hand is best described as an optimisation problem. Telemetry data provided by the car instrumentation system can be analysed to help identify driving patterns, specifically car-handling mistakes. The identification of these behaviours, which traditionally employs pattern recognition techniques, represents a challenge in itself. Behaviour recognition is key to providing corrective measures in order to improve the driving performance of a given user. In particular, it is the starting point in building a model which maps telemetry data to corrective measures for presentation to the user in real-time and deferred fashion, where even the visualisation of feedback is critical to the success of such a system.

4 Background

4.1 Motorsport racing

In sports individuals or groups compete to be first to achieve a particular objective. In the case of circuit motorsport races, in which motorised vehicles go round a course. Each racing discipline or series has its own rules. However, at the core, all disciplines participants aim to complete a full lap of the circuit in the least amount of time. Some disciplines focus on achieving one fast lap, such as time trials, while others focus on achieving the least amount of time across a fixed amount of laps, such as FIA's Formula 1 series. This dissertation will focus on confined car racing taking place on smooth asphalt surfaces in purpose built race tracks.

4.1.1 Racing Line

A race driver needs to figure out how to go round a piece of asphalt in the minimum amount of time [14]. In order to do so, he or she needs to develop techniques for more advanced vehicle control. One such technique is that of mastering the race line, which is considered the the fundamental skill a race driver must understand and master before moving on to anything else [14]. The racing line is the best path through a circuit, it is the path which takes the least time while keeping the higher average speed [5]. The trickiest part of the racing line to master is that of a corner, this task is split into two parts, identifying the line which should be taken and staying on the line. The first part refers to being able to visualise the racing line while the later refers to actually being able to control the car so that it stays on the line. Once the driver has an idea of the race line which the corner should be taken at, he or she must further split the line into three sections. The first part is the braking part, during this part the driver needs to decelerate in preparation for the corner, this is usually carried out in a straight line and end right before the turn in point. The turn in point refers to a point on the corner race line in which steering input is applied, allowing the car to turn into the corner. The turn in motion should be a smooth one, taking the car all through the corner without having to do too much corrections to the steering. Being smooth while cornering allows the G-forces and centre of gravity of the car to not be abruptly effected which would result in unpredictable car behaviour [14]. The aim of the turn in section is to aim for the apex point, this is the inside middle point of the corner. The final part of tackling a corner is the acceleration part, after the apex point, the driver must start to gradually accelerate out of the corner while still turning out of the corner aiming for the outside apex.

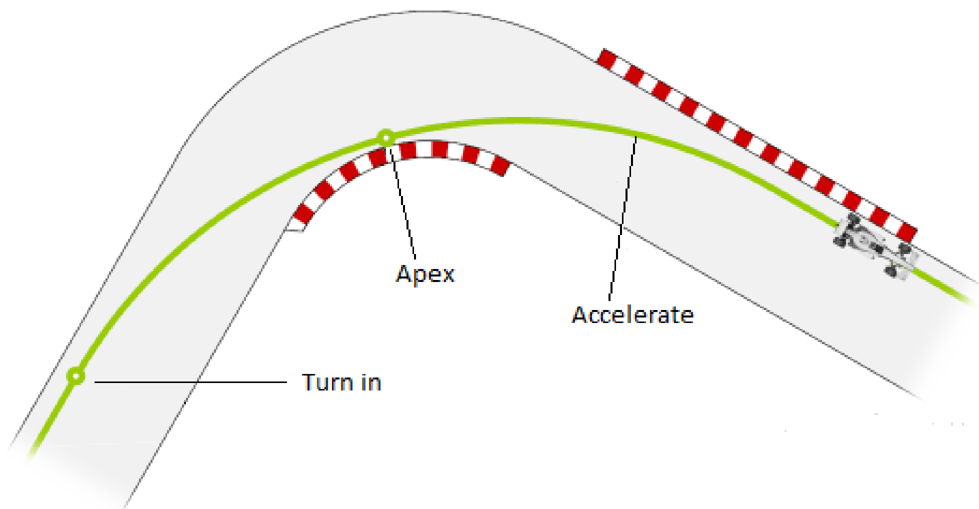

Figure 1: Race line through a 90" right corner

After the driver manages to drive the race line at a relatively slow speed, the driver must find the limit of the car. This is the maximum speed the car can be driven while still allowing the driver to have maximum control over the car. Various studies have been carried out to define such a limit in terms of the physical properties of the car and environment around it. The most important property is the level of grip the car can achieve and sustain on track. Various factors contribute to the level of grip, most notable are the tires which the car is being driven on, as the tires are the only actual contact to the track, allowing for braking, accelerating and turning forces to be transferred to the asphalt [5].

Each tire has two properties which are of particular interest to a drive, the slip angle and slip ratio. The slip angle is the angle between a tires direction of travel and the actual direction the tire is going towards. Given both the actual direction of travel and desired direction of travel are known, it becomes trivial to calculate the angle which is done by calculating the arch of the two vectors as shown in 4.

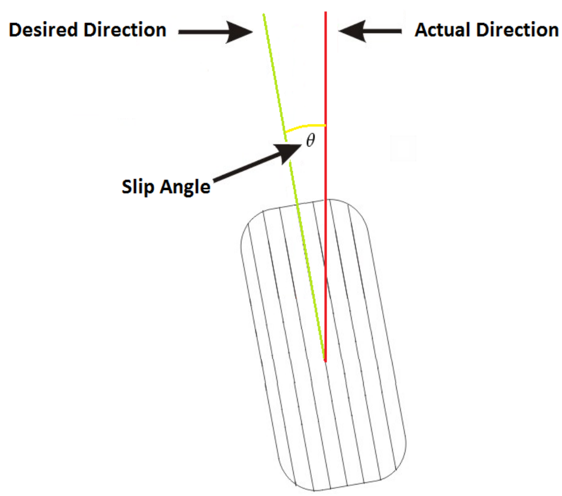

Figure 2: Slip Angle of a tire understeering while turning left

4.1.2 Cornering and braking

Whenever the slip angle is above 0 the tire is described as being in an understeering situation. Symptoms include Light steering, drifting towards the outside of a bend and possible tyre noise from the wheels. Assuming the tires are not damaged and the track is not wet nor dirty, understeer can be caused by active factors such as cornering speed throttle, braking, steering inputs and weight transfer. Other passive factors such as Weight distribution, drive layout, suspension and chassis setup, tyre type, wear and pressures also effect understeer. An understeer situation in a corner can be avoided by not entering too fast into a corner, not accelerating too aggressively in a corner, not braking through a corner, and not making any sudden changes which drastically upset the weight distribution of the car. Passive factors have to do with the way a car is mechanically setup, such factors will be taken in consideration during this project but will not be given great importance as this project aims to improve the drives skills. The project will focus on the active factors as these are the ones which the driver has direct input on while driving a car. It is known for a tire to have an optimal slip angle, this is the slip angle at which the tire can produce the most grip while cornering. A common road tires optimal slip angle is of 5 while a slick tire which is purpose built for racing has an optimal slip angle of 8-10. These values may vary a bit depending on the tire brand [5]

Moving on to oversteer, this is an other issue which can arise from lack of grip. Whereas understeer is caused by lack of grip in the front tires, oversteer is caused by lack of grip on the rear tires. Symptoms of oversteer include having the rear of the vehicle becoming unstable and 'light' and the car starts to rotate so the driver is facing towards the inside of the corner. Active factors causing oversteer are cornering speed, throttle, braking, steering inputs and weight transfer. The driver can avoid oversteer by not braking while in a corner and not accelerating too hard in a rear wheel drive as it makes the rear tires spin too fast, losing traction with the road.

During acceleration and braking the tire experiences rotational forces, however these rotational forces do not match the expected velocity, this means at all time there is some level of slip occurring between the tire and the road beneath it. This slip is called slip ratio and is expressed in percentage. A slip percentage of 100% would mean the tire is rotating, but the road is stationary, this is called a burnout or wheel spin. On the other hand, a percentage of -100% would mean the tire is not rotating but the road beneath it is moving, this can occur while braking hard and is called locking the wheels [17]. While braking the driver must make sure not lock up the tires as this will cause the tires to wear out quicker while also drastically increasing the stopping distance. On the other hand braking too lightly will make the car take longer to decelerate with

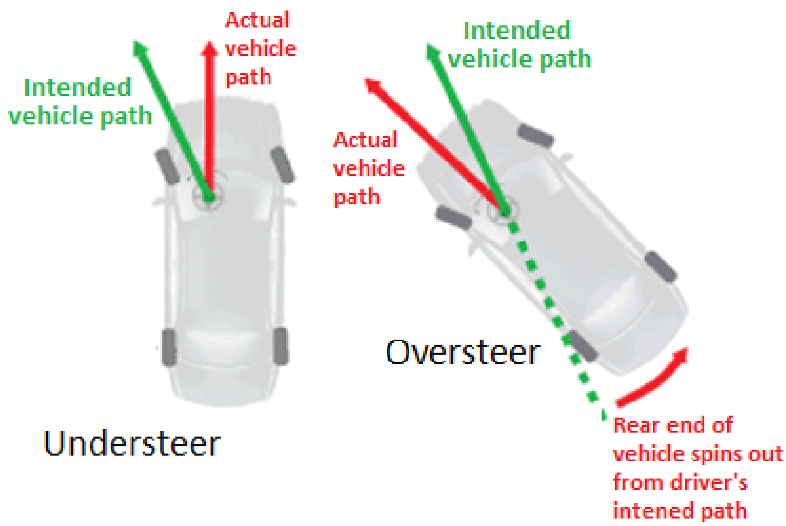

Figure 3: Visual representation for oversteer and understeer

makes the driver lose time. In order to braking optimally the slip ratio should be between 10% to 15% [14].

4.2 Racing Rigs

Moving on from the real world into the simulation world in which a racing rig is an integral part of achieving an authentic feel to the simulation experience. Racing rigs vary in price starting from a bundle with a steering wheel and pedal set costing less than 100 to ones used by professional racing teams costing thousands. The difference in price is partially due to built quality, but the biggest contributing factor is attributed to how well the rig mimics the real world. This is achieved by integrating force feedback, butt kickers and hydraulic pistons. Racing rigs can be categorised by four price range brackets. Entry level refer to the cheapest price range, racing rigs in the range offer the basics to get some one up and running.

The most basic racing rig is one which only has Steering wheel, than more sophisticated ones are made by adding pedals, shifters, racing seat, mounting frames and hydraulic pistons. Butt kickers and hydraulic pistons are commonly integrated in high end rigs such as ones built by Vesaro. Force feedback is a form of haptic technology which used to replicate the forces which are transferred through a steering wheel in a car onto the driver [12]. Butt kickers and hydraulic used to simulate lateral and longitudinal forces which a race driver is exposed to during racing.

Figure 4: Professional racing rig by Vesaro

5 Literature Review

5.1 Video games and Serious Games

Baranowski et al [21] define games as a physical or mental contest with a goal or objective, played according to a framework, or rule, that determines what a player can or cannot do inside a game world. The definition covers the setup of a game, while a physical or mental contest, played according to specific rules, with the goal of amusing or rewarding the participant the reward aspect of games.

Video games are built on top of these core values with the addition of having the game world confined to some sort of digital medium. The first video game was created by William Higinbotham; it was a tennis game to be played on a television set [19]. From the early days of video games, their main aim was always to provide some degree of entertainment. The entertainment value is achieved in various ways depending on the gaming platform, game genre and the target audience. Modern video games are simply made up of three fundamental components: story, art and software [22].

Moving on to serious games this type of games are considered a mix of simulation and game to improve eduction [3]. The idea behind a serious game is to connect a serious purpose to knowledge and technologies from the video game industry [15]. The boundaries of serious games are debated, mostly due to the fact that serious games attract multiple domains making it hard to come up with a common boundary. However, the common denominator across all domains seems to be serious game designers use people's interest in video games to capture their attention for a variety of purposes that go beyond pure entertainment [6].

The main contrast between video games and serious games is the use of pedagogic activities which aim to educate or instruct knowledge or skill [22] in serious games as opposed to the pure leisurely aspects of the video game. Pedagogy is given preference over the amusement value which in some cases might not be found in serious games [22]. All serious games involve learning, whether eye hand coordination skills, visual-spatial skills, which buttons to push or what to do in a certain scenario. This is the fundamental difference between serious and entertainment games. Serious games need to educate the player with a specific type of content, whereas entertainment games need to entertain the player with whatever; racing, puzzles, it does not really matter, as long as the player enjoys it [9]. With an entertainment game, development's main objective is too make the game fun, the content and controls should be at the service of making the game entertaining, On the other hand, serious game designers have multiple objectives, they still need to create a compelling and fun game, but also an educating and realistic game. From this it follows that three aspects as essential for a serious game, fun, learning and validity [9]. One should not forget that a serious game is fundamentally a game, and a game should be fun. The game should make use of pedagogical methods and theories to ensure knowledge can be conveyed. Validity is related to the content which is being tackled in the serious game. The content which is being taught should teach relevant content that can be applied outside of the game world.

5.1.1 Pedagogy

In order to produce a valid pedagogical experience aspects as learning objectives, target groups and challenges needs to be clearly identified before designing a serious game [16]. Various pedagogy theories exist which can be applied to a serious game, some of which are behaviorism, cognitivism, constructivism and situated learning [7]. From each of these theories one can extract some important properties.

Experience Games tend to provide learning-by-doing, Many games make use of pop-up windows with extensive amount of text that are supposed to have educational value. This technique could provide too much information, time pressure or other factors inside a game environment which could potentially lead to cognitive overload or lead a person to filtering out critical information [7].

Exploration An important property of a game is that of requiring an active, participative attitude of the learner. The game world, including rules, mechanics and environment need to be explored and discovered by the learner. Many poorly designed games force the player to do something, while they should just let the player figure it out or at least guide the player into doing so.

Incremental The learning process should occur incrementally as it will otherwise be too demanding for a player, and that is the way the human brain functions. Humans acquire knowledge piece for piece and try to integrate this into existing structures [16].

Deciding on a pedagogy is no easy task, one must take into account the aims and objective which is the pedagogy task is trying to achieve while also considering any capabilities and limitations the target audience might have. Such consideration must be made when designing the way information is channelled back to the user. Three main channels are considered, auditory, visual and kinaesthetic. The choice of which to use relies heavily on the domain and the end user. Some instructions might be able to be better conveyed through visual cues, while other work better as auditory or kinaesthetic, however, previous work found out that a mix of channels work better as one can complement the other [10]. Such cases include instances in which timing is a factor, having a visual image further explained with audio or vice versa. A further consideration has to be made when applying this to the vehicle driving context, it is important avoid or at least minimise the effect such channels might have on the concentration of the driver. The driver is already focusing by keeping eyes on the road, usually focusing on the centre of the road ahead also keeping in the look out with rapid eye glancing at any obstacles in the vehicle surrounding area and staying attentive for any auditory cues coming from the environment which could highlight any danger [8].

5.2 Sim Racing

Simulation racing games (sim racing) such as Asseto Corsa [1] and Project CARS [2] , which are off-the-shelf products, provide a sim racing experience within budget for the average video game consumer. The aim with such games is to replicate real life cars, race car dynamics and track locations to amuse and entertain the player. The challenge aspect is achieved by pitting the user against other computer drivers known as AI players, or in multiplayer online races, which are played against other human players. In some cases, a user can compete against oneself by taking on a ghost - a recording of the player's best lap for a particular track. Sim racing the definition of what a video game is however, they miss the pedagogy activities which would qualify them as serious games. Most of the modern sim racing games do aid the player to improve by means of implementing aids. Such aids might include showing the racing line while also highlighting the braking and acceleration points. Other aids include anti lock brakes, traction control and stability control, these are implemented in a passive way. With the exception of the racing line, the player is not told when and what is being done wrong. This results in users having to figure out their own mistakes by means of practicing without any guidance or feedback from with the game. This final year project aims to implement a module which is plugged into an off the shelf racing simulator which. This module trains users by letting them know what is being done wrong, when it's being done wrong and most importantly how to avoid making the same mistake. Further more this project builds on the premise put forward which shows that users are able to learn road driving skills into a virtual world and then successfully applying them to the real world [12] [20]. Although studies have been carried out involving training for road drivers, none have looked into teaching on racing circuits with the aim of improving racing and car handling techniques.

6 Research Methodology

This chapter provides a detailed exposition of the methodology used throughout this work. This study has conducted exploratory and descriptive research to determine whether the use of simulation and an automated feedback driven system, a user can be trained as a race driver. The chapter is structured as follows: § 6.1 provides a general overview of the overarching methodology used in the study, § 6.3 describes in length the design of the instrument used to acquire experiment data and results, § 6.4 presents the experimental procedure and the rationale behind it, § 6.5 identifies the information and data acquired through the experimental and descriptive methodologies employed, and finally § 6.6 presents the data analysis mechanisms employed to substantiate our conclusions.

6.1 Overview

This study conducted experimental and descriptive research on the viability of the use of simulators in conjunction with an automated feedback system for improving race driving skills in the normal population. Specifically, a user study was devised and carried out with the primary goals being:

1. To determine whether a context-based feedback system can improve the skills of a participant

2. To quantify the magnitude of this improvement, if (1) is true

These goals were addressed by means of an experimental setup based on a race-driving simulator, using which objective measurement of the participant performance could be gathered and analysed, and a questionnaire for relating the participant's experience with the experimentally-gathered data. The setup of the experiment is explored in more detail in § 6.3.

Since the main goal of this study is that of assessing how effective a feedback system is in the learning process, the independent variable in the experiment is the ability to receive feedback. The hypothesis is that participant performance (such as average lap time) is improved through feedback, and is thus a dependent variable. However, practising without feedback can also lead to changes in the dependent variable; therefore this is controlled for by having two groups of participants: the experimental group that receives feedback and the control group that doesn't. Random assignment is used to determine a participant's group.

A questionnaire, to be administered to the participants at the end of the session, will be designed to help normalise and control for other factors that may influence dependent variables, and hence, the outcome of the experiment. The design of the questionnaire also helps in bridging the participants' perception of their performance with the actual performance data, possibly providing further insight into the results. A questionnaire was preferred to an interview because it is easier to administer, it lends itself to group administration and also allows confidentiality. It is indeed true that interviews permit a greater freedom of expression on behalf of the participant; however, questionnaires create a sense of anonymity that encourages the participants to be more truthful in their answers [11].

6.2 Experiment Design

In the experiment, each group would be utilising the same car and racetrack. Bastow et al. [4] suggest that cars equipped with a front wheel drivetrain may be easier to handle. The Fiat 500 Abarth was the car chosen for the experiments, partially based on Bastow et al.'s findings. The car is relatively low-powered and thus, easier to use by beginning drivers. The Silverstone National race track has the desirable properties of being flat and smooth, without uneven surfaces or bumps which may result in loss of control in rookie drivers. Furthermore, the way the track is structured, with wide run-off areas located along the circuit where drivers are most likely to lose control of the car, allows the car to slow down before colliding with barriers or other stationary objects.

Two feedback mechanisms have been considered for this experiment, *visual*,

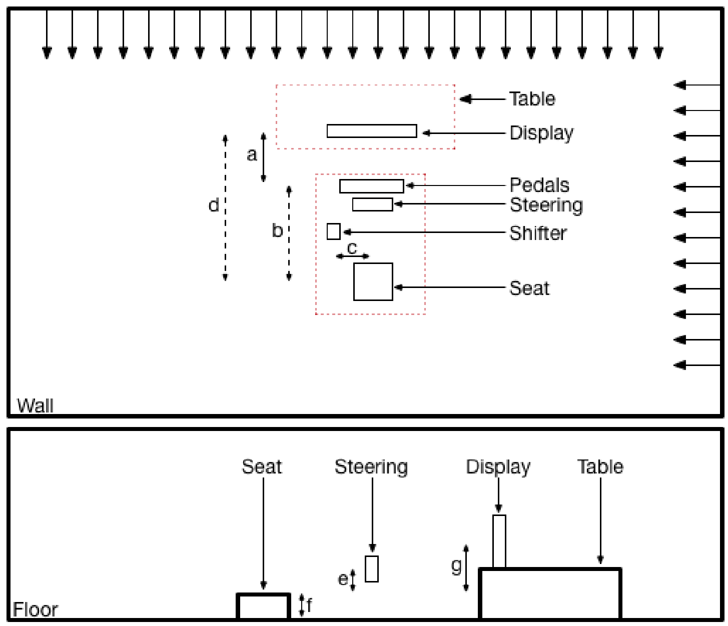

Figure 5: Top-down and side views of experiment setup

through the use of a heads-up-display (HUD) superimposed on the simulation display, or *auditory*, by means of descriptive speech projected through loud speakers. Leahy et al. [10] argue that auditory feedback is less intrusive that visual clues; based on these findings, it was decided that the system should provide feedback using auditory clues.

6.3 Experiment Materials

The setup of the experiment was divided into three material categories: *simulation environment*, *simulation hardware* and *simulation software*, with each category subscribing to a number of desirable properties:

Environment The experiment should be carried out in an isolated, noise-free and well-lit room. Participants would be let in the room one at a time, to ensure the experiment is conducted without any distractions.

Hardware The hardware components identified for this experiment are the (i) display output, (ii) steering wheel, (iii) gear shifter, (iv) acceleration, brake and clutch pedals and (v) seating frame.

Display Xi haga fuq id-display (Make, model, resolution)

Driving Controls The driving controls include (ii)-(iv); minimally a steering wheel should provide the same number of revolutions as a racing car, providing accurate force feedback to let the participants accurately assess the behaviour of the car. Gear shifters do not implement feedback mechanisms; however, given their ubiquity, H-shifters are preferred since they are the kind most drivers are familiar with. High-end pedal systems use hydraulics to simulate the variability of force required on part of the driver to actuate a pedal during different stages of a drive.

Seating frame The seating frame should ensure a seating position akin to a driver in a racing car. Details re: adjustability.

Software Extract properties from commented para below:

To add tabulated properties for the choices considered and rationale for the final equipment/software procured.

6.3.1 Questionnaire

Questionnaires allow for further insight from the point of view of the participants. Leary et al. provide seven guidelines for compiling a questionnaire [**?**]:

1. being specific and precise in phrasing the questions

2. writing the questions as simply as possible, avoiding difficult words, unnecessary jargon, and cumbersome phrases

3. avoid making unwarranted assumptions about the respondents
4. conditional information should precede the key idea of the question
5. do not use double-barrelled questions
6. pretest the questions

Responses from questionnaires designed using these guidelines are valid in the general case. The challenge in choosing a response format in a question lies in identifying whether one should go for an open ended question in which more information might be collected, or on the other hand, use a rating scale response format, where the response is more constrained but may be easier to analyse. Leary et al. suggest using the former for questions dealing with behaviours, thoughts, or feelings that can vary in frequency or intensity (e.g. the Likert Scale [13]) and using open ended questions in cases where further insight is desired.

Based on these guidelines two qualitative questionnaires have been designed, one aiming to gather insight into the sample demographic, the other aiming to gain insight into the participants' impressions about the realism of the experiment setup, the level of comfort, or discomfort and any suggestions or comments they might have.

6.4 Procedure

In order to evaluate the effectiveness of the system a user study took place. Participants were split randomly into two groups. One group will be referred as the feedback group, the other will be referred to as the base group. The experiments structure was subdivided into smaller systemic tasks.

Demographic questionare At the start on the experiment the demographic questionare is to be handed out to the participant.

Adjust Rig Configuration In order for the participant to sit comfortable while also ensuring all controls can be reached with ease, the rig has to be configured per participant. This involves having to move the seat further back or forward to the steering wheel, as it would be done in a real car. In addition participants are also told how to operating the rig. The explanation covers the steering wheel turns two and a half turns from lock to lock, the pedals are setup as on any manual road car, having the clutch pedal on the left, brake in the middle, and throttle on the right. The H shifter is also explained by having a run through demonstration of all gears which allows participants to be able to operate the rig with out having to learn on their own.

Breaks To avoid having driving sessions possibly put too much strain on participants, optional five minute breaks are allowed to be taken between driving sessions.

Ten minuties practice During these ten minutes users are told to simply get used to the rig setup, track and car. The aim of this session is for participants to get used to the setup while also allow this study to measure their skill before the feedbvack system as the independent variable is introduced.

Two Ten minuties sessions These are the sessions in which the feedback system is turned on for the feedback group, while the participants in base group are left to keep trying to improve without any aid.

Five minuties session A final five minuties of driving are allocated yet again, this time with the feedback system turned of for both groups. This was designed to possibly identify any conclusive results. Such session could show the possibility of the feedback group performing worst after having the aid of the feedback system removed or both groups ending up perofmring the system after the sessions suggesting the feedback participant didn't manage to get any cognitive advantage.

Particpant's feedback questionare The final stage of the experiment requires participants to fill in the a questionnaire in which they are asked to give their feedback on the experiment structure, hardware used and any further comments they would like to add.

6.5 Data Collection and Sampling

At the end of the experiments the data collected includes two questioners from each participant and four batches of telemetry data, one for each participant. Questioners are filled online using Google Forms as it provides the ability to export the data and also automatic generation of descriptive statistic in conjunction with representing the results via data visualisation techniques such as bar charts and pie charts. The data collected from the questionnaires and telemetry data is to be loaded into a data base management system from which the data can be queried using specialised data querying constructs. This is done as the telemetry data collected contains around 200,000 records per participant, which proved to be too much to handle at once during analysis. By having a querying language, it provides the flexibility of extract data which is relevant for the data analysis at hand.

6.6 Data Analysis

In order to accept or reject the null hypothesis tests for mean scores on two independent groups. By carrying out this test one is able to determine to a level of confidence the effect caused by the introduction of the independent variable, which in this case refers to the feedback system. The lap time is used as the test variable as this gives a good indication for the average performance achieved during a lap.

https://statistics.laerd.com/spss-tutorials/mann-whitney-u-test-using-spss-statistics.php For dataset small than 2000 elements, we use the Shapiro-Wilk test, otherwise, the Kolmogorov-Smirnov test is used. In our case, since we have only 20 elements, the Shapiro-Wilk test is used Normality tests are to be carried out to determine the distribution. After which it will be possible to use Independent samples t-test [18] as the distribution was normally distributed, from such test one can determine the degree of influence in the introduction of a variable has had over a group. In case the data is not normally distributed the non parametric Mann Whitney test as there is no need to assume a normal distribution.

7 Implementation

7.1 Supporting tools

7.1.1 Track Splicer

This project is designed to work with any race track given specific track meta data is provided to aid the feedback system processing. The meta data is split into two files, the first is the race line file which contains data from which the feedback system can determine the race line a user should stick to. For this particular study the race line files have been generated from an .ai file which is supplied with Assetto Corsa. Each track has an associated 'ideal_line.ai' file associated with it. The ai file contains raw bytes, which through manual investigation of the file in hex view, it was noted the file is made of a header part of 36 bytes, followed by a sequence of repeating records of 20 bytes each. These records contain four floats and one 32bit integer, storing the data which is required in the raceline.csv file. The records in the ai file are read via a custom developed command line tool and translated into the csv format required by the feedback system.

Moving on to the sections.csv, this file is also a coma separated file containing a sequence of records. These records denote corners and straights which make up the track, and will be used to compute any feedback which is specific to straights or corners. In order to generate this file a tool has been developed which loads the raceline.csv and computes the rate of change from one data point to the next. Depending on the rate of change the points are classified as either part of a straight section or as a corner section. This is done by taking three points, p1, p2 and p3 from which two vectors are generated v1 and v2. V1 is the vector from p1 to p2, and v2 is the vector from p2 to p3. Then, v1 and v2 are normalised and the dot product computed which give out the rate of change in radians. The pseudo code for this is shown below.

for (i = 0; i ¡ racelinePoints.Count - 2; i++)

```
{
Vector2 v1 = racelinePoints[i].GetVectorToPoint(racelinePoints[i+1]);
Vector2 v2 = racelinePoints[i+1].GetVectorToPoint(racelinePoints[i+2]);
V1 = Vector2.Normalize(v1);
V2 = Vector2.Normalize(v2);
float dotProduct = Vector2.Dot(v1, v2);
double difference = Math.Acos(dotProduct);
}
```

The corner mid-point can be defined as the highest section of the arch. In order to find this, it is simply a matter of finding the highest possible vector dot product from the section starting point, to the end of the section. The pseudo code is shown below.

```
Point p = endPoint - startPoint;
Vector2 n = new Vector2(-p.Y, p.X);
Int idOfMax = -1;
float max = -1;
for (i = trackSection.StartPoint; i ¡= trackSection.EndPoint; i++)
{
p = _RacingLine[i] - startPoint;
float result = Vector2.Dot(new Vector2(point.X, point.Y), n);
result = Math.Abs(result);
if (result ¿ max)

max = result; idOfMax = i;

}
```

6 shows the tool in action which also provides a visual representation of the race line. Corner sections are shows are show are red dots, with green dots used

to highlight a corners mid-point and straights are shown in blue.

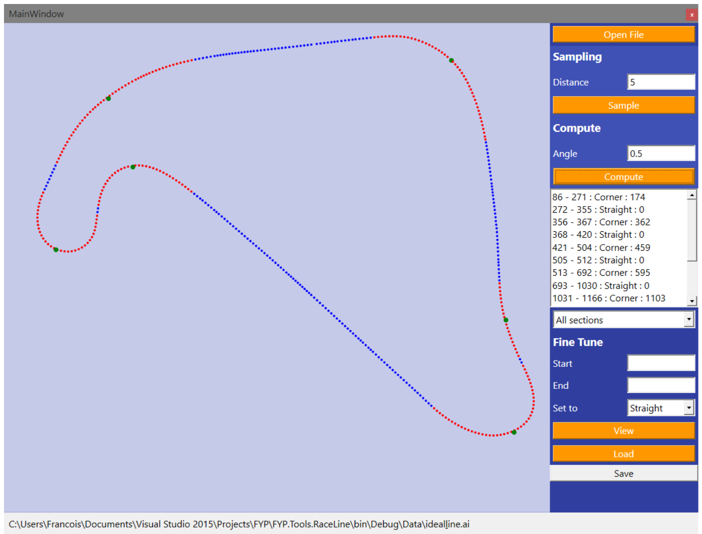

Figure 6: Track splicer tool

7.1.2 Spatial Querying

As previously mentioned it is important for the feedback system to be able to carry out fast spatial querying operations. A query for the nearest race line data point based relative to the current position of the car is required to be carried out multiple times per second. Thanks to the implementation of a quad tree, the search guaranteed to take place in O(logn), while insertion is done O(nlogn) however, this is not too relevant as all insertion are carried out before the feedback system starts its computations. This structure allows the feedback to quickly calculate in which section of the track the car is located, the nearest race line data point and how far from the race line the car is.

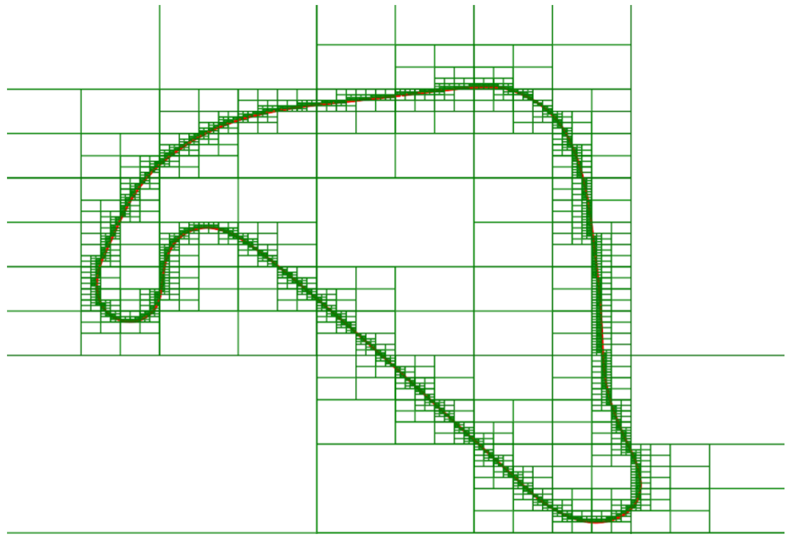

Figure 7: Visual representation for part of the quad tree

7.2 System Architecture

7.2.1 Sim Racing Rig

The rig is made out of various independent components. The steering wheel is a G25 purpose built by Logitech, an electronic steering wheel designed for sim racing video games. It has a 900 degree range of rotation, two force feedback motor and comes as package which includes a pedal set and an H shifter. The pedal set is made of three pedals, from left to right, a clutch pedal, brake pedal and an accelerate pedal. The H shifter simulates one which is found cars fitted with a manual gearbox, the shifter simulates six gears and one reverse. The steering wheel, pedals and shifter are mounted on a home made metal frame which mimics the position of these components as they would be placed in a race car. The last component of the rig is the seat, which is a bucket racing seat which has been taken of a real race car and fitted to racing rig.

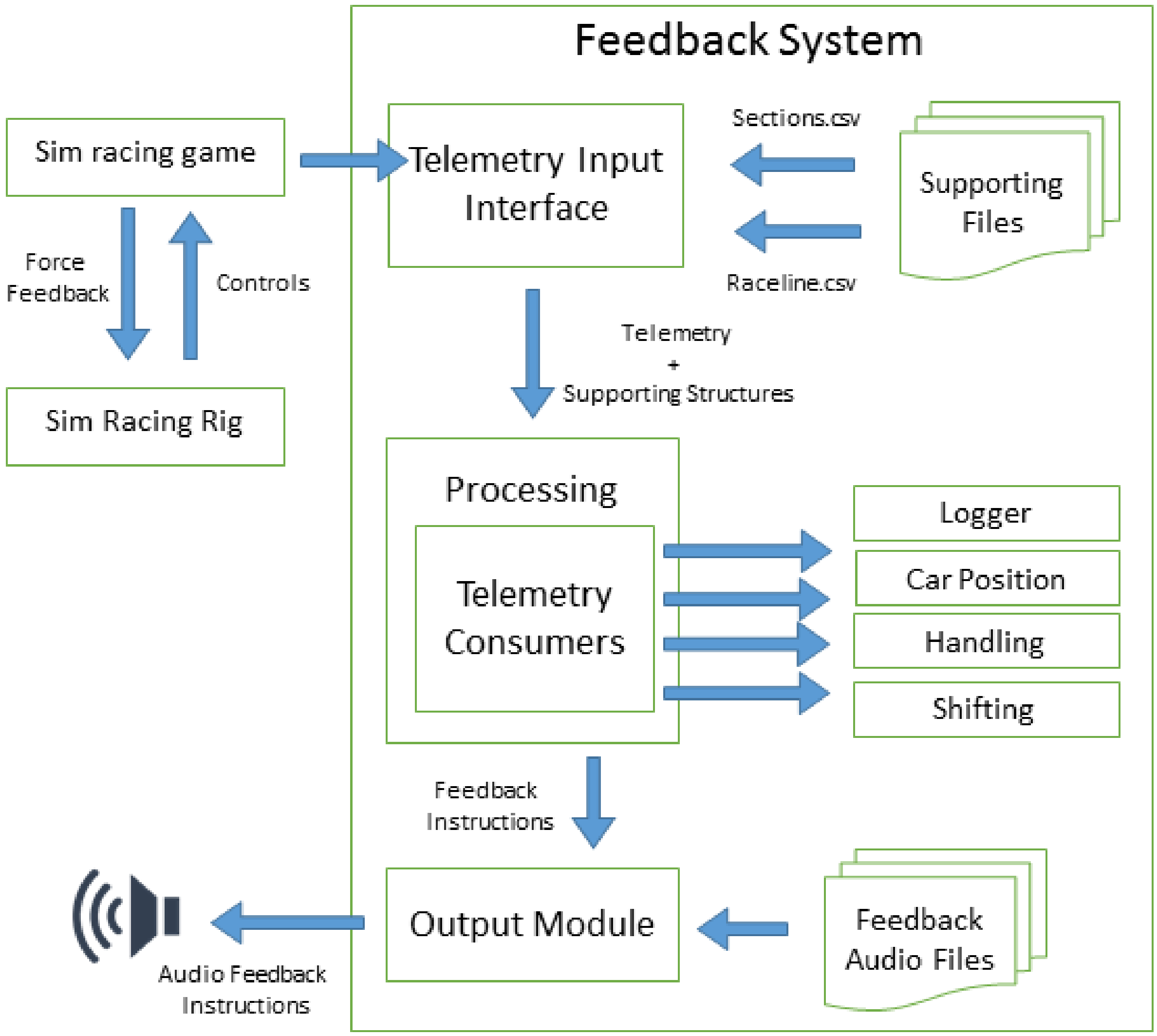

Figure 8: Overview of the system architecture components

7.2.2 Feedback system

Software development of the feedback system has been achieved using C# and Microsoft's .Net framework. The feedback system is made up of smaller components which pass data to each other in order to produce the feedback instruction which should be output to the user. Below is the break down of each component including an over of their inner workings.

Figure 9: Side view of the racing rig

7.2.3 Telemetry Input Interface

This components handles and data inputs which are required feedback to be generated. Two type of inputs are required, static inputs and real time. The static inputs are the ones which have been previously generated by the supporting tools, the raceline.csv and sections.csv. From these files the quadtree is generated and stored in memory where other components can access. Real time input refers to telemetry generated from the sim racing game. Assetto corsa provides a UDP server which a client can connect to, which the connection is established the game will send telemetry data in raw bytes. The telemetry input interface fetches these bytes, parses them into a C# struct, and forwards the struct to the processing component.

7.2.4 Processing

Feedback processing is split into sub modules. Each module runs on a separate independent thread and gets a copy of the telemetry data passed in real time as it becomes available. The modules carry out computation on the data looking for potential issues with the users driving. In case the a modules finds an issue, a message is sent via .Net delegates to the parent processing component. Since the feedback modules run independently from each other, the processing component acts as a coordinator by passing data to them, and acting as a delegate for any feedback notifications which might get generated.

Optimisation is also carried out within this component. This is achieved by having the feedback getting filtered before being propagated to the output module by an expert system. The knowledge base of the expert system is a hand crafted static one, based of rules and facts extracted from the literature. The inference engine works in a tiered skill based manner. As soon as the system starts, only instructions from the basic tier are given. After the user manages to get better feedback instructions for the next tier are added to the output. In addition each module has a tolerance associated to each feedback notification it can provide. This allows the expert system to adjust how strict a module should be in raising a notification and be able to gradually make the system stricter as the user improves.

7.2.5 Feedbacks being provided

The pseudo code will be provided in the appendix as not to clutter this section

Handling component monitors for braking and acceleration behaviours. It is able to raise the following feedback notifications,

- Braking too hard
- Braking too light
- Braking in corner
- Losing traction to the drive wheels by applying too much power

Car Position component monitors for any issues which might cause the user to not adhere to the race line. As such this module can raise the following notifications

- Incorrect race line during corner
- Being too aggressive during a corner
- Not slow during a corner
- Track section report

Shifting component monitors how the user is changing gears, which allows it to raise the following notifications

- Changing gear to soon
- Changing gear to late
- Taking too long to transition from one gear to another

7.2.6 Output Interface

Each possible feedback instruction which can be generated by the processing module has a static audio file associated to it. The audio files are generated from a free on line text to speech tool. The purpose of this component is to listen for feedback instruction generated by the processing component and play the corresponding audio file.

8 Evaluation

8.1 Demographic of the Sample

The following demographic data was drawned out from the pre study survey. Participant's were mostly in their early twenties and mostly males. Out of 27 participants, 2 didn't have a driving license and 25 had a driving license with most of them have been driving for a year. Furthermore 22 participants identified them self as playing videos games, from which 18 participants stated they have played racing video games. The majority of participants who plays racing games identified them self as playing mostly arcade sim racing games, while only 3 play sim racing games. Out of the 27 participants, 7 participants have previously used a racing rig.

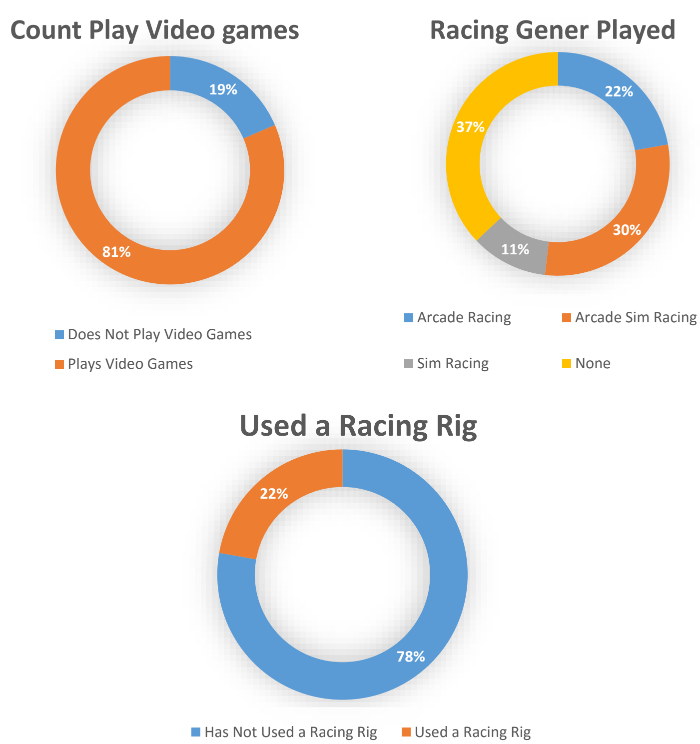

Figure 10: Video games experience

8.2 Distribution tests

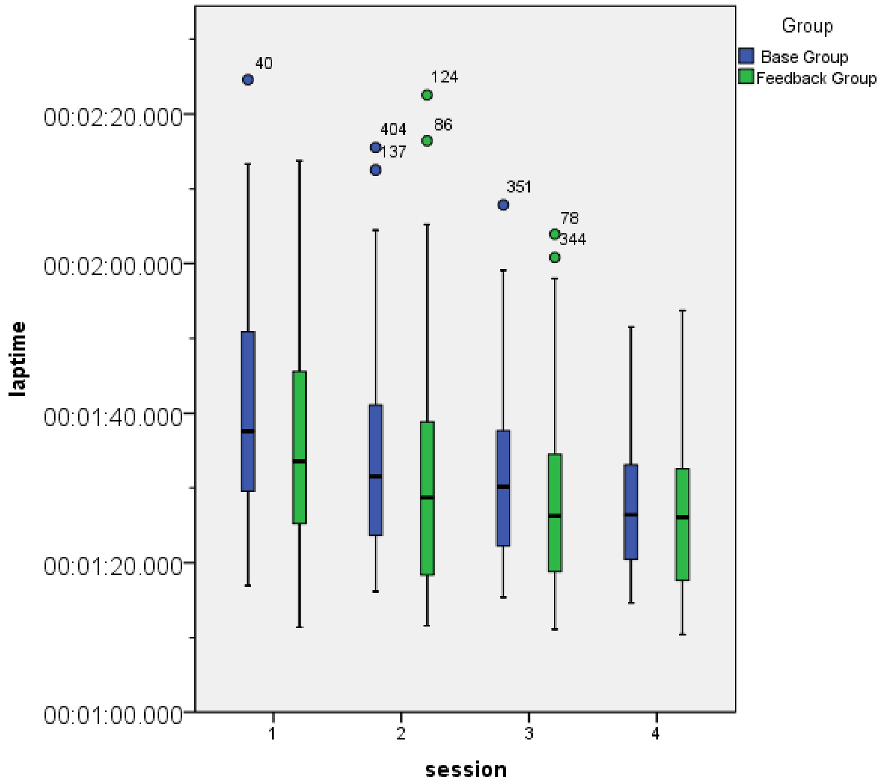

Figure 11: Lap times vs session, clustered by group

Carrying out Shapiro-Wilk test for normality for the feedback group and base group during the first session on their respective lap times it was found that the data is not normally distributed as the p-value for both groups is below 0.05 resulting in rejecting the null hypothesis stating the samples come from a normal distribution

The same data was checked for similar distribution across groups using the Independent Samples Kolmogorow-Smimov Test which resulted in accepting the null hypothesis stating the groups' lap times share the same distribution.

Tests of Normality

Group		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
LapTime	Base Gro	.108	70	.042	.955	70	.013
	Feedback	.074	81	.200*	.963	81	.020

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 12: Shapiro Wilk test results

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of LapTime is the same across categories of Group.	Independent-Samples Kolmogorov-Smirnov Test	.360	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 13: Kolmogorow Smimov test result

8.3 Feedback system results

Having established both groups' lap times share the same distribution during the first session the Mann-Whitney Test to determine any differences between the groups before the feedback system is introduced. The test results show a p value of 0.057 resulting in no statistical difference between the groups at the start of the sessions.

Running the Mann-Whitney test on the remaining sessions, results show there is no significant difference between the two groups even after the feedback system was introduced to one group. The third session tells a different story as the p value is 0.029 which results is accepting the null hypothesis. The fourth and final sessions is the one which both groups had the feedback system turned off which resulted in the difference between the groups to yet again show no statistical significant difference.

Ranks

Group		N	Mean Rank	Sum of Ranks
LapTime	0	70	83.29	5830.50
	1	81	69.70	5645.50
	Total	151		

Test Statistics[a]

	LapTime
Mann-Whitney U	2324.500
Wilcoxon W	5645.500
Z	-1.905
Asymp. Sig. (2-tailed)	.057

a. Grouping Variable:

Figure 14: Mann-Whitney test result

Mann-Whitney Test

	LapTime		
	2nd Session	3rd Session	4th Session
Mann-Whitney U	2662.000	2718.000	754.000
Wilcoxon W	6317.000	6634.000	1657.000
Z	-1.923	-2.188	-.614
Asymp. Sig. (2-tailed)	.054	.029	.539

a. Grouping Variable: Group

Null hypothesis	There is a sig differnce
Alternative hypothesis	There is no sig differnce

Figure 15: Mann-Whitney test result for the last the sessions

9 Future Work

Having the feedback system control an AI car. More data analysis Observer the user for mistakes such as not keeping both hands on the wheel resting the hand on the shifter and not looking into a corner.

Teach users in the sim, have them drive in real life.

Whether by the end of the project all the original aims and objectives have been completed or not, there is always scope for future work. Also the ideas will have grown during the course of the project beyond what the student could hope to do in the time available. The Future Work section is for expressing these unrealised ideas. It is a way of recording 'I have thought about this'. A good Future Work section should provide a starting point for someone else to continue the work which has been done.

Have the expert system go also back a tier if the user is going backwards, not just forward

At present only negative feedback is given, a good idea would be to look into the benefits of letting the user know when a particular task has been completed correctly.

10 Conclusion

The Conclusions section should be a summary of the project and a restatement of its main results, i.e. what has been learnt and what it has achieved. An effective set of conclusions should not introduce new material. Instead it should draw out, summarise, combine and reiterate the main points that have been made in the body of the dissertation and present opinions based on them.

11 Glossary

12 Charts

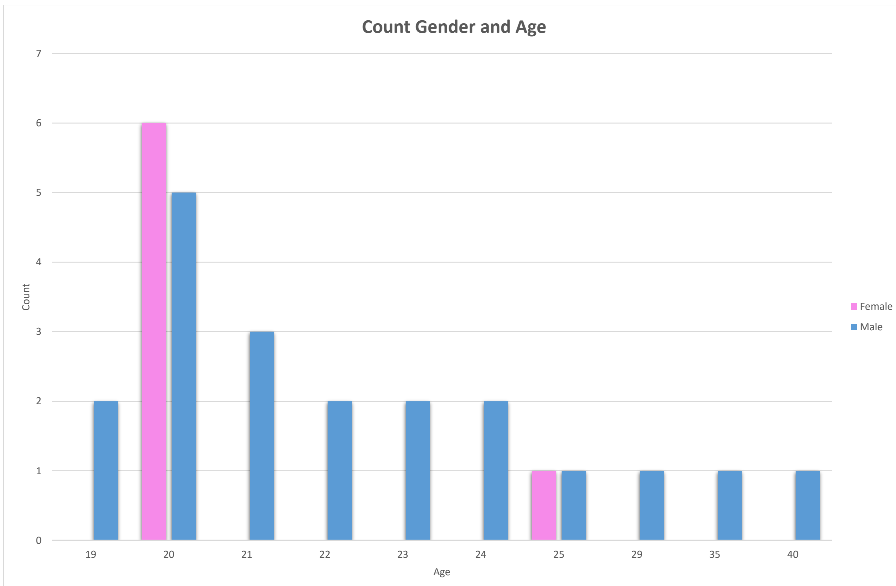

Figure 16: Count Participants' gender and age

Transcript of the audio files

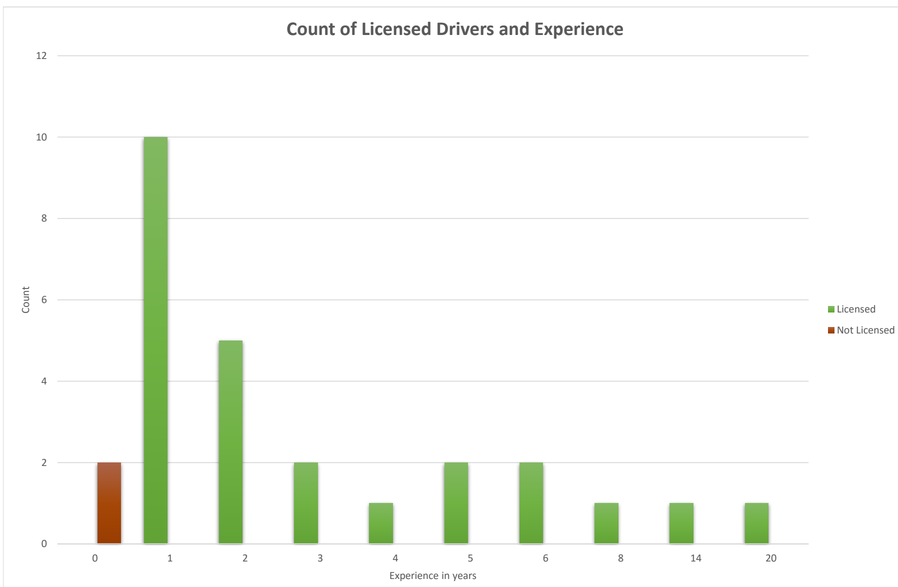

Figure 17: Licensed drivers and experience

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