Telemetry-based Optimisation for User Training in Racing Simulators

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Abstract

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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.

Acknowledgements

Luke for racing rig

Keith and Sandro

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Chapter 1

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 [27] has validated the use of serious games beyond their initial military use in training strategic skills [15]. 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 [15] and emergency service providers (e.g. firefighters [27]) 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.

1.1 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.

1.2 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.

Chapter 2

Background

This chapter introduces motorsport racing and a number of related concepts that are essential in gaining an understanding of this work. The chapter opens with a brief overview of the sport, followed by an exposition of important concepts like the *racing line*, cornering and braking. A discussion ensues, wherein *understeer* and *oversteer* are explained. A short overview of telemetry is then provided. The chapter concludes with a general introduction to simulation racing rigs.

2.1 Motorsport Racing

In sports, individuals or groups compete to be the first to achieve a particular objective. In circuit motorsport racing, motorised vehicles go round a course for a set number of times. There are varies racing disciplines or series, each one having its own specific rules. However, at the core, participants in all disciplines aim to complete a full lap of the circuit in the shortest 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 number of laps, such as FIA's Formula 1 series. This dissertation will focus on one such discipline, that of confined car racing, which takes place on smooth asphalt surfaces in purpose-built race tracks.

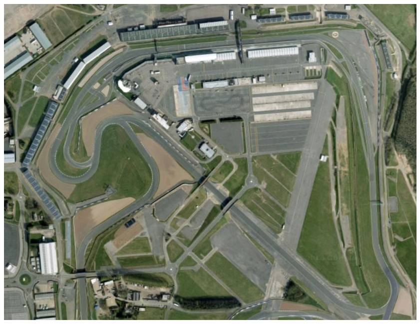


Figure 2.1: Example of confined car racing circuit

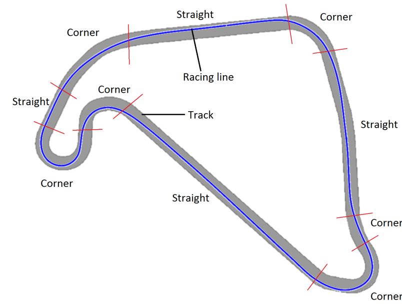


Figure 2.2: Example of racing line, straights and corners

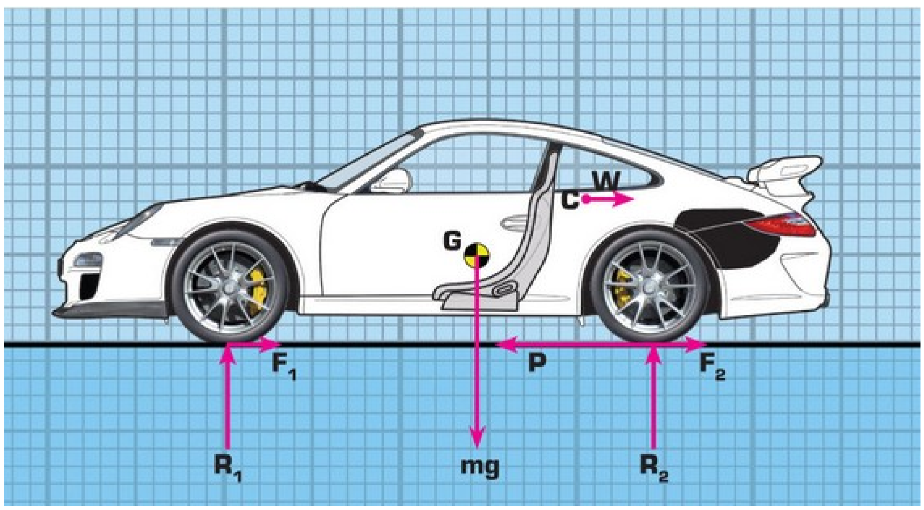


Figure 2.3: Forces acting on a car [1]

mg The cars weight, which is a force acting at G, the centre of gravity

R1, R2 Upwards reactions to mg

F1, F2 Rolling frictional forces acting at the wheels, always in the direction opposing motion.

P The engines torque, converted to a force P between the rear tyres and the road.

W Drag

2.1.1 Racing Line

A race driver needs to figure out how to go round a piece of asphalt in the minimum amount of time [26]. 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 racing line (see Figure 2.2), which is considered the fundamental skill a race driver must understand and master before moving on to anything else [26]. The racing line is the best path through a circuit: if followed, it is the path that yields the shortest time at the highest average speed [13]. The trickiest part of the racing line to master is that which overlaps circuit corner segments (see Figure 2.2). There are two aspects to mastery of the racing line: first, one has to identifying the path which should be taken, and secondly, one must stay on that path. In the first instance, one has to be able to visualise the racing line, while in the latter one has to control the car such that it stays on the line whilst achieving the highest possible average speed. Once the driver can visualise the racing line, he must further partition it, at and near a corner, in three sections. The first section is the breaking part, where the car needs to sufficiently decelerate in preparation for the corner. Braking is usually carried out in a straight line, ending right before the *turn-in point*. The turn-in point refers to a point on the racing line where steering input is applied, forcing the car to turn into the corner. This action should be carried out smoothly, without jerking motions, taking the car all through the corner without too much correction to the steering. Smooth cornering prevents any abrupt changes to the g-forces and centre of gravity of the car (see Figure 2.3), which would result in unpredictable car behaviour [26]. Thus, the second partition of the racing line at a corner is the segment between the turn-in point and the apex point, which is the inside mid-point of the corner (see Figure 2.4). After the turn-in point, the driver aims for the apex point. The final section of the racing line in a corner lies from the apex point onwards, where the driver must gradually accelerate out of the corner, while still turning, aiming for the outside apex (see Figure 2.4.

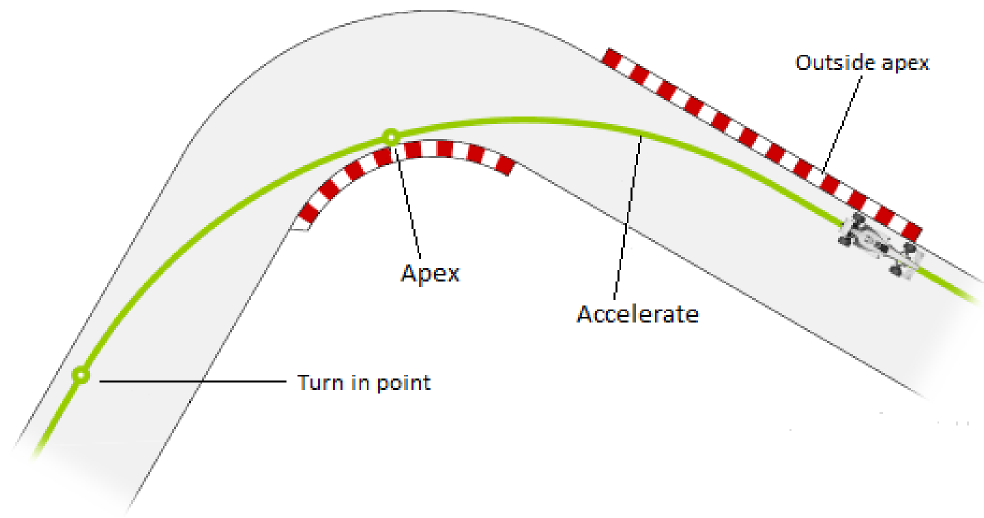


Figure 2.4: Racing line through a 90” right corner

As the driver gets acquainted to the racing line, usually at sub-optimal speeds, he must find the limit of the car, which is the highest speed the car can be driven while still retaining some measure of control. Various studies have been carried out to define such a limit in terms of the physical properties of the car and its environment [13]. The most important property is the level of grip the car can achieve and sustain on track. A number of factors contribute to the level of grip. Most notably, one very important factor is the tyres as they are the only contact the car makes with the track, and allow for braking, accelerating and turning forces to be transferred to the asphalt.

Each tyre has two properties which are of particular interest: the slip angle and slip ratio (see Figure 2.5). The slip angle is the angle between the tyre's desired direction (perpendicular to the axis of rotation of the tyre) and the tyre's actual direction (the direction the car is moving in). Given both the actual direction of travel ($\mathbf{d}_t$) and the desired direction ($\mathbf{d}_d$) are known, the slip angle s_a is calculated as follows:

$$s_a = \cos^{-1}(\hat{\mathbf{d}}_d \cdot \hat{\mathbf{d}}_t), \tag{2.1}$$

where $\hat{\mathbf{d}}_d = \frac{\mathbf{d}_d}{|\mathbf{d}_d|}$ and $\hat{\mathbf{d}}_t = \frac{\mathbf{d}_t}{|\mathbf{d}_t|}$ are the normalised direction vectors for desired and travel directions respectively.

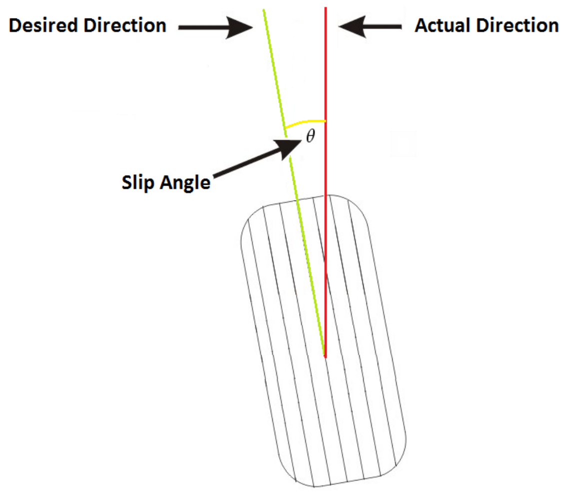


Figure 2.5: Slip Angle of a tyre understeering while turning left

2.1.2 Cornering and Braking

Whenever the slip angle is above $0°$ ($s_a > 0$) the tyre is said to be in an understeering situation. Symptoms include reduced friction, drifting towards the outside of a bend and possible tyre noise from the wheels. Assuming the tyres are not damaged and the track is neither wet nor dirty, understeer can be caused by active factors such as cornering speed, throttle application, 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 affect understeer. An understeer situation may be caused by entering the corner at excessive speed, accelerating too aggressively in the corner, breaking through a corner or making sudden input changes which drastically upset the weight distribution of the car. A tyre has an optimal slip angle at which grip is maximised during cornering. The optimal slip angle for a road tyre is about $5°$, whereas for a slick tyre, which is purposely constructed for racing, is about $8° - 10°$ [13].

An oversteering situation may arise from lack of grip; while understeer is caused by a lack of grip in the front tyres, oversteer is cause by a lack of grip on the rear tyres. Oversteer is usually denoted by the rear of the vehicle becoming unstable resulting in its rotation such that the driver is facing towards the inside of the corner. Similarly to understeer, the active factors causing oversteer are also cornering speed, throttle application, braking, steering inputs and weight transfer. Oversteer is usually induced by braking during a corner or accelerating too hard in a rear wheel drive vehicle.

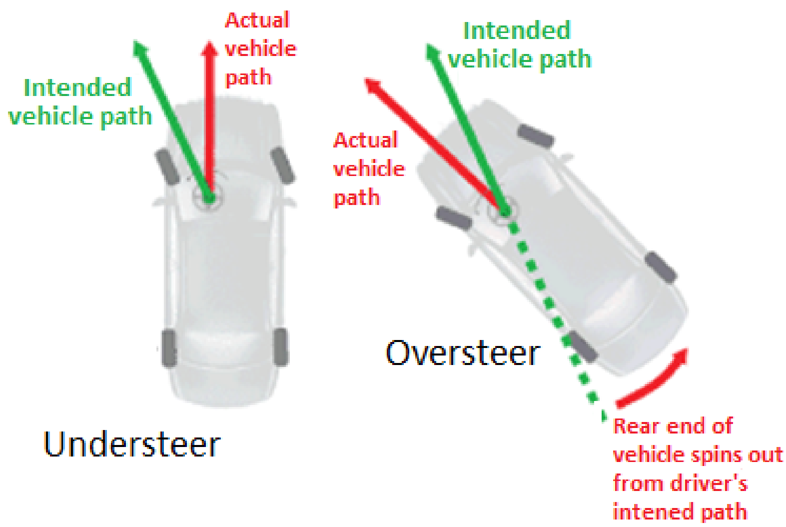


Figure 2.6: Visual representation for oversteer and understeer

During acceleration and braking the tyre experiences rotational forces; when these rotational forces do not match the expected velocity, there is some level of slip occurring between the tyre and the road. This is referred to as *slip ratio* and is expressed as a percentage: a slip percentage of 100% means that the tyre is rotating but the road is stationary. In jargon, this is called *burnout* or *wheel spin*. On the other hand, a percentage of -100% indicates that the tyre is not rotating but the road beneath is moving. This can occur when braking too hard and is called *locking the wheels* [29]. While braking the driver must avoid locking up the tyres as this will cause them to wear out more quickly, while drastically increasing the stopping distance. Conversely, braking too lightly makes the car decelerate at a slower rate, losing the driver precious time. For an optimal braking procedure, the slip ratio should be between 10% to 15% [26].

Passive factors, which depend on the mechanical set up of a car, may also influence car behaviour during cornering and braking. However, in this work, any passive factors will be normalised and kept constant across all the study to eliminate any possible effects on dependent variables.

2.1.3 Telemetry Data

Telemetry (literally remote measurement), is the automated communications process by which measurements and other data are acquired from remote or inaccessible objects or sites, to be subsequently monitored [10]. Telemetry data is domain specialised data that contains such measurements, transmitted to receiving equipment for remote monitoring. In motorsport, telemetry data contains measurements of vehicle dynamics from the engine and other components. These measurements can serve to monitor and reconstruct the vehicle state at a particular point in time. Telemetry data in motorsports usually accounts for measurements of speed, engine speed, component temperatures, slip angles, slip ratios, etc. Telemetry is widely regarded as the most important source of information by motorsports engineers; analysing this data can lead to a better understanding of the respective strengths and weaknesses of the car and the driver [21]. In this work, we posit that through the real-time analysis of telemetry data, the pedagogical aspect of sim racing can be exploited to teach race driving to non experts.

2.2 Racing Simulation Rigs

The racing simulation rig (sim racing rig) is a piece of equipment designed to mimic the cockpit of a real-world car (see Figure 2.8). The quality of a sim racing rig is dependent on its authenticity - how similar it is to a real-world car

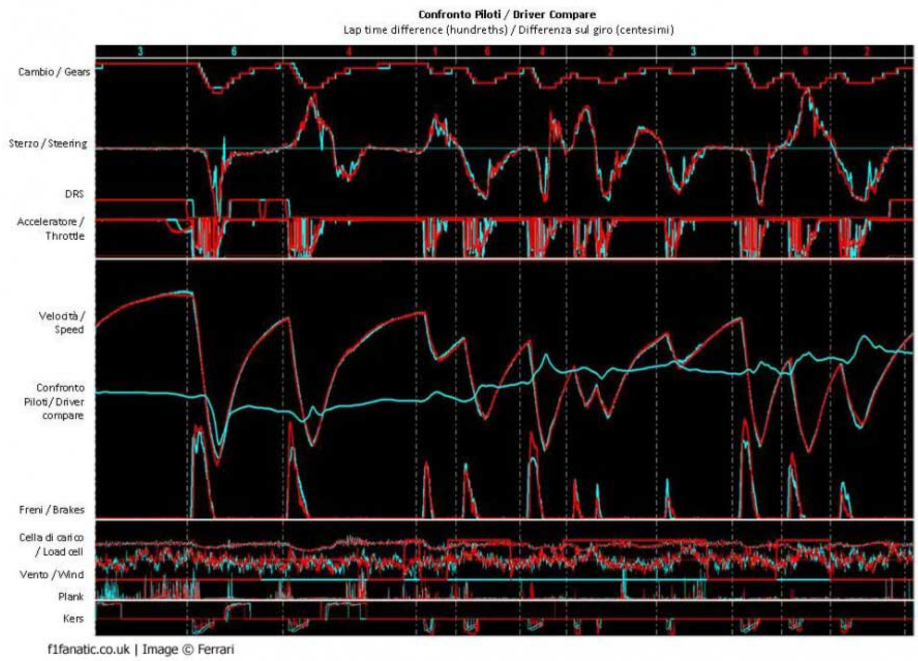


Figure 2.7: Visualisation of racing car telemetry data

- and its build quality. These rigs come in various shapes, forms and sizes, from hangar-sized hydraulic-driven car chassis, that cost millions of Euro, to the more modest, built from off-the-shelf commodity hardware. Minimally, a rig should provide a steering wheel, seating and a display. More sophisticated rigs augment the user experience by employing gear shifters, and clutch, throttle and breaking pedals. The more advanced components are furnished with a force feedback mechanism, a form of haptic technology used to replicate the sense of touch by applying forces or vibrations, or motions to the user [24]. Force feedback may be caused by electrical motors, gear trains or hydraulic systems. In high-end rigs, for instance, hydraulic systems are used to simulate the latitudinal and longitudinal forces to which a driver is exposed during driving. Modern rigs might include virtual reality headsets as a replacement for displays, to enhance immersion and increase realism.

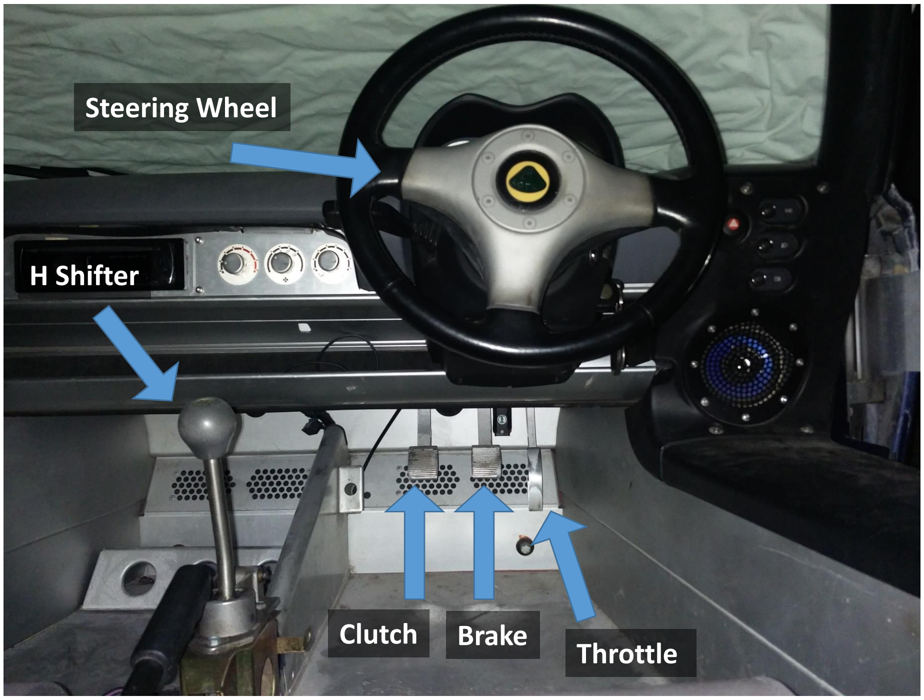


Figure 2.8: Typical race car cockpit

2.3 Summary

Figure 2.9: Entry level racing rig

Figure 2.10: High end consumer racing rig

Figure 2.11: High end commercial racing rig

Chapter 3

Literature Review

This chapter provides a brief exposition of the state of the art and related work in race driving simulation. The chapter starts by drawing a distinction between video games and serious games, and motivates this demarcation. This is followed by a discussion of the pedagogical aspect of serious games. Finally, an overview of simulation racing is given, with a focus on the genre's intersection between entertainment and pedagogical factors.

3.1 Video Games and Serious Games

Baranowski et al [32] 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 [30]. 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 [33].

Moving on to serious games this type of games are considered a mix of simulation and game to improve eduction [11]. The idea behind a serious game is to connect a serious purpose to knowledge and technologies from the video game industry [27]. 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 [15].

The main contrast between video games and serious games is the use of pedagogic activities which aim to educate or instruct knowledge or skill [33] 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 [33]. 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 [19]. 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 [19]. 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.

3.1.1 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 [28]. Various pedagogy theories exist which can be applied to a serious game, some of which are behaviorism, cognitivism, constructivism and situated learning [16]. 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 [16].

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 [28].

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 [22]. 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 [17].

3.2 Racing Simulation Games

Racing simulation games (sim racing) such as Asseto Corsa [4] and Project CARS [8], 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 [24] [31]. 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.

3.3 Summary

Blah Blah

Chapter 4

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: § 4.1 provides a general overview of the overarching methodology used in the study, § 4.3 describes in length the design of the instrument used to acquire experiment data and results, § 4.4 presents the experimental procedure and the rationale behind it, § 4.5 identifies the information and data acquired through the experimental and descriptive methodologies employed, and finally § 4.6 presents the data analysis mechanisms employed to substantiate our conclusions.

4.1 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 § 4.3.

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 [23].. 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 [23].

4.2 Experiment Design

In the experiment, each group would be utilising the same car and racetrack. Bastow et al. [12] 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*, 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. [22] argue that auditory feedback is less intrusive than visual clues; based on these findings, it was decided that the system should provide feedback using auditory clues.

4.3 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) audio output, (iii) steering wheel, (iv) gear shifter, (v) acceleration, brake and clutch pedals and (vi) seating frame.

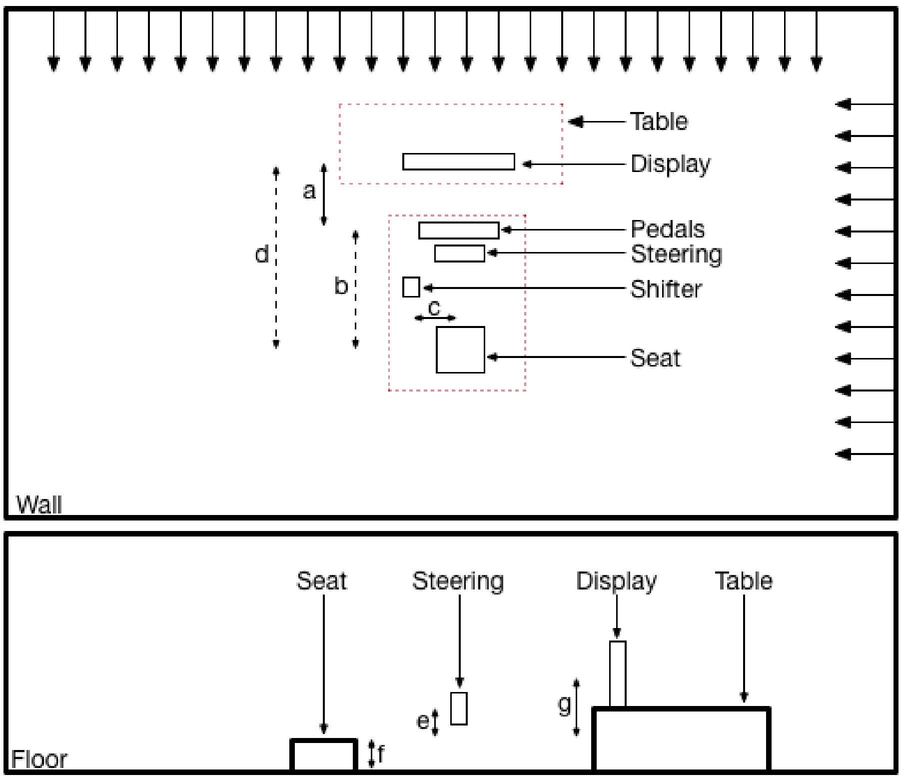


Figure 4.1: Top-down and side views of experiment setup
a = 45cm, b = 75cm, c = 36cm, d = 120cm, e = 20cm, f = 30cm, g = 35cm

Display and Audio A 32"+ display capable of outputting graphics at a progressive resolution of 1080 pixels vertically at 60 Hz (1080p60) is required; smaller display sizes would not yield a large enough solid angle for the participant to feel immersed in the simulator. For audio output, a stereo setup with a speaker output power of 10W should be sufficient; at a distance of 1m, these speakers can generate sound volume up to 100db, where normal conversation is around 60db.

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.

Seating Frame The seating frame should ensure a seating position akin to a driver in a racing car. The seating frame should also provide the ability to move the seat back and forward in order for participants to be able to seat comfortable and be able to reach the pedals.

Software The software aspect of the experiment, which is primarily the racing simulator, should have a number of desirable properties. In particular, the simulator should provide (i) a realistic driving model, (ii) driving aid customisation, (iii) high-fidelity graphics, (iv) real-world tarmac circuits, (v) and telemetry data access through an interface that is intuitive to use.

Realistic Driving Model For this experiment, a realistic driving model is a sine qua non. Recreating real-world conditions requires a high-fidelity physics simulation of race car dynamics that is as close to the real thing as possible.

Driving Aid Customisation Required to control experiment variables, such as tyre wear and tear. The aim is to prevent car behaviour from changing as the experiment progresses.

High-fidelity Graphics Required to provide the participant with a fully immersive experience.

Real-world Tarmac Circuits Most racing simulators accurately replicate real-world tracks, up to minute details such as elevation changes and bumps. This level of realism exposes participants to real-life scenarios. Furthermore, the simulator should provide circuits that loop, to streamline experiments and remove the need to reset the software in order to drive another lap.

Telemetry Data Access The premise of this project hinges on the ability to read telemetry data from a simulator. Thus, any software that does not provide this feature is a priori discarded. However, easier and cleaner interfaces for reading telemetry data, and the breadth of telemetry data offered, are a deciding factor in the choice of racing simulator to use.

4.3.1 Hardware Selection

A number of racing simulator input devices have been considered (see Table 4.1). The choice was narrowed down to the most popular devices among racing game enthusiasts, the Logitech G25 [2], the Thrustmaster TX [9] and the Fanatec CS [5]. The G25 provides the minimally required features: a steering wheel with a 900° turn, 3-pedal set, H-shifter and force feedback; furthermore, the G25 is also a very affordable device. Both the Thrustmaster and Fanatec are high-end devices, which explains the cost difference. Furthermore, neither come with the 3-pedal set and the H shifter, which have to be purchased separately. The Logitech G25 was chosen for being the most cost-effective of the three options.

Device	900°	**3-Pedal Set**	**H-Shifter**	**Feedback**	**Cost**
Logitech G25	✓	✓	✓	Low	240
Thrustmaster TX	✓			Med	324
Fanatec CS	✓			High	850

Table 4.1: Comparison of input devices

4.3.2 Software selection

Similarly to the hardware selection process, a number of racing simulators have been considered (see Table 4.2). Although there is a myriad of racing simulators available, the selection process narrowed them down to a popular handful: Forza Motorsports 6 [6] by Turn 10 Studios, Project Cars [8] by Slightly Mad Studios, Assetto Corsa [4] by Kunos Simulazioni, iRacing [7] by iRacing.com Motorsports Simulations and Dirt [3] by Codemasters. Unfortunately, notwithstanding its quality, Forza Motorsports 6 does not provide access to telemetry information. Dirt also suffers from the same shortcoming, in addition to providing very little in terms of track applicability: very few tracks are circuit-based. iRacing provides most of the functionality required by the experiment, however in terms of visual quality it suffers when compared to Project Cars and Assetto Corsa. Finally, the choice between Assetto Corsa and Project Cars was made on the basis of ease of interfacing for the acquisition of telemetry data; here we felt Assetto Corsa provided a clean, intuitive and ultimately superior interface to telemetry acquistion via User Datagram Protocol (UDP) connections.

Simulator	**Driving Model**	**Driving Aids**	**Visual Quality**	**Tracks**	**Tele-metry**	**I/F Ease**
Forza	✓	✓	✓	✓		
Project Cars	✓	✓	✓	✓	✓	
Assetto Corsa	✓	✓	✓	✓	✓	✓
iRacing	✓	✓		✓	✓	✓
Dirt	✓	✓	✓			

Table 4.2: Comparison of racing simulators on the basis of a realistic driving model, customisable driving aids, high-fidelity graphics quality, applicability of tracks, availability of telemetry information, and ease of interfacing.

4.3.3 Participant Information and Feedback

Questionnaires are a very important tool for acquiring insight from the point of view of experiment participants, and when compared to interviews, they provide a framework within which respondents can answer more truthfully due to lack of social external pressures. Leary et al. [23] provide a set of guidelines for compiling questionnaires, consisting of seven general rules:

1. Be specific and precise in phrasing the questions;
2. Write 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. A further challenge posed by questionnaire compilation is that of choosing a response format for each question: open-ended questions may serve to collect more information but be less conducive to analysis, while on the other hand, more restrictive and constrained response formats may lack expressivity but be easier to analyse. Leary et al. suggest using constrained response formats, such as the Likert scale [25], when dealing with behaviours, thoughts or feelings that can vary in frequency or intensity, and open-ended questions in cases where further insight is desired.

Two qualitative questionnaires have been designed in accord with these guidelines, one with the aim of gathering insight into the participant demographics, and a second to help normalise and control for factors that may influence dependent variables, to bridge the participants' perception of their performance with the actual execution, and to gather other insight and feedback about the experiment.

4.4 Experiment Procedure

In this section, we describe in detail the experiment procedure. Participants are gathered through various methods, ranging from word-of-mouth to mailing lists, where each participant would reserve an experiment time slot. Participants are split randomly into two groups. The first group is referred to as the *feedback group*, the second as the *control group*.

Introduction Each participant is introduced to the setup and given an overview of the experiment procedure.

Demographic Questionnaire The experiment starts by the participant responding to a brief questionnaire, aimed to gather more insight about the general participant demographics.

Rig Configuration The user climbs inside the rig; the seating position is adjusted to accommodate the user, making sure he or she is sitting comfortably, and all controls can be reached with ease. Participants are given a second, more in-depth overview of the components of the rig and how they operate. This explanation covers the steering wheel, the pedal layout and function and the H-shifter.

Practice (10 minutes) The participant is given ten minutes to get used to the rig setup, track and car. This session is aimed at gauging the skill level of the user while he or she gets acquainted with the simulator.

Break (5 minutes) A short break (5 minutes maximum) is given to each participant.

1^{st} **Session (10 minutes)** In this session, the participant drives the racing car around the track for ten minutes. Participants in the feedback group have the feedback system turned on, while for the control group, this is turned off.

Break (5 minutes) A short break (5 minutes maximum) is given to each participant.

2^{nd} **Session (10 minutes)** A second ten minute session is held; participants in the feedback group have the feedback system turned on, while for the control group, this is turned off.

Break (5 minutes) A short break (5 minutes maximum) is given to each participant.

3^{rd} **Session (5 minutes)** A final five minute driving session; the feedback system is turned off for participants in both groups. This session was included to help identifying conclusive results about the feedback system and its effects on the participants.

Feedback Questionnaire The experiment concludes by the participant responding to a questionnaire about experiment structure, apparatus quality, performance perception and free-form participant feedback.

4.5 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. 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. By having a querying language, it provides the flexibility of extracting data which is relevant for the data analysis at hand.

4.6 Data Analysis

In order to accept or reject the null hypothesis statistical test are to be carried out. Most important is the ability to compare the performance of the two groups across sessions. The lap time is used as the test variable as this gives a good indication for the average performance achieved during a lap. Furthermore which comparison test to use depends on the sample size, the distribution of data and the types of group. In this case the groups are independent from each other, as a participant may not be part of the base group and also part of the feedback group. As pointed out by De Smith in his book "Statistical Analysis Handbook-a web-based statistics" the tests of interest to this project are the Independent samples t-test [14] and the Mann Whitney U test [14] as these test for difference between independent groups. Both tests share the same hypothesis listed below.

Independent t test assumes the data is normally as such the data must be checked for normal distribution. This can be carried out by using the Shapiro-Wilk [14] test for normality on both groups.

Mann Whitney U test Does not require the data to be normally distributed however, it assumes the groups' data shares the same distribution. The groups are checked for equal distribution using the Independent Samples Kolmogorow-Smimov test.

Null hypotesis there is no significant difference across the groups

Alternative hypotesis there is significant difference across the groups

As the data distribution is not known before hand, distribution tests will be carried out after the data is collected and depending on the result, the adequate test will be used.

Chapter 5

Design and Implementation

This chapter provides a detailed description of the design and implementation of the software artefact employed in this project. The chapter starts by giving an overview of the core requirements for the main software artefact which we refer to as *Telemetry Assisted Racing (TeAR)* (see Section §5.1). Section §5.2 discusses the tools developed to create content for the feedback system, including track annotation and racing line visualisation amongst others. The chapter concludes with an in-depth description of the internals of the feedback system, the respective components, their integration and communication 5.3.

5.1 Requirements

Deliberation on the methodologies provided in Chapter 4 led to a number of requirements being identified for the software artefact. These requirements are listed below:

- Content creation and annotation
- Interfacing with third-party racing sim software
- Efficiently read and process incoming telemetry stream
  - Filter the stream for noise and unnecessary detail

    - Structure raw data to facilitate further processing

- Develop a heuristic-based system to provide feedback
- Provide a mechanism for communicating feedback to user
- Persist telemetry data for further processing

Circuit information coming from third-party software, such as the racing line, must be available to TeAR; furthermore, this data is to be annotated with additional information such as track section partitioning and the respective properties, which are fundamental in determining which feedback to provide to the user. Thus, a number of supporting tools have to be developed. TeAR must interface with the third party racing simulation software (Assetto Corsa) via the inter-process communication system provided by the program. In addition, TeAR must extract a stream of telemetry data from the simulator, at a sampling rate of approximately 333Hz (which is the sustained rate provided by Assetto Corsa on the experiment's hardware). The incoming telemetry data must be filtered since not all data is useful to TeAR. Furthermore, these data are organised into structures that are more conducive to processing later on in the pipeline. This telemetry information will be fed into a heuristic-based algorithm that should return feedback that will eventually be presented to the user. This feedback should be the most effective correction the user would need to make to improve that particular race track section. TeAR should communicate this feedback to the user via an auditory messaging system. Finally, all telemetry data should be persisted onto secondary storage for offline analysis.

5.2 Content Creation and Annotation

The telemetry data stream read-out from Assetto Corsa does not provide sufficient information about the environment for TeAR to make informed decisions about possible feedback. The feedback mechanism used in TeAR is highly dependent on the racing line, which in turn, is a function of the track geometry;

however, it is not possible to acquire any meaningful information about the racing track from telemetry data alone. These factors prompted the creation of the *Track Splicer and Visualiser*, a supporting tool that extracts track information from the Assetto Corsa data files and provides additional annotations to this data as required by TeAR.

5.2.1 Track Splicing

The track splicing tool extracts track and racing line information from Assetto Corsa, partitions the data into a number of sections that are annotated as either straight or corner, and finally finds the apex of each corner section. The tool also provides visualisation of the results in case the user needs to tweak the generation parameters. This process is shown in Figure 5.1.

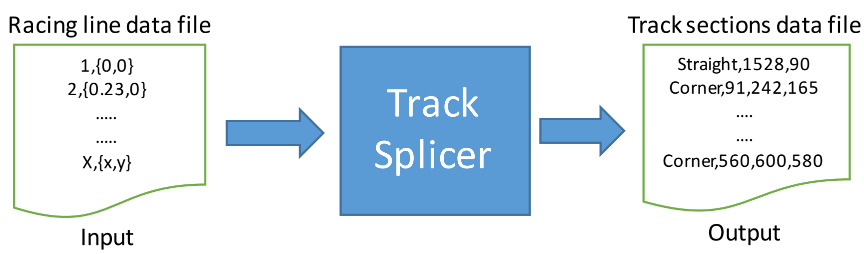


Figure 5.1: Track splicer input and output

Track Partitioning The idealised racing line is a simple closed curve $\mathcal{C}$ on a plane; its digital counterpart is a discrete simple closed curve $\mathcal{C}_d$ with a finite number of vertices, each lying on the curve $\mathcal{C}$ and connected by straight edges - an inscribed polygon - where each vertex $\mathbf{v}_i \in \mathcal{C}_d$ represents a coordinate pair (x, z). The ground is assumed to be a horizontal plane. To determine whether a section of the track near a vertex $\mathbf{v}_j \in \mathcal{C}_d$ is a straight or a corner, two further vertices are sampled $\mathbf{v}_i, \mathbf{v}_k \in \mathcal{C}_d$, where $i < j < k \in \mathbb{Z}/|\mathcal{C}_d|\mathbb{Z}$. We define the measure of curvature c_j for the curve at $\mathbf{v}_j$ as follows:

$$c_j = \cos^{-1}\left(\frac{\mathbf{v}_k - \mathbf{v}_j}{|\mathbf{v}_k - \mathbf{v}_j|} \cdot \frac{\mathbf{v}_j - \mathbf{v}_i}{|\mathbf{v}_j - \mathbf{v}_i|}\right), \tag{5.1}$$

where c_j is the angle between the two normalised unit vectors formed by the ordered vertices $\mathbf{v}_i$ through $\mathbf{v}_k$. A threshold value c_t determines whether the curve segment from $\mathbf{v}_i$ through $\mathbf{v}_k$ is a corner or a straight. A typical value for c_t is 0.01. Edges between consecutive vertices in $\mathbf{C}_d$ may vary in length; therefore, when vertices $\mathbf{v}_i$ and $\mathbf{v}_j$ are chosen, Poisson-Disc sampling is employed, to guarantee that the vertices are no closer to each other than a specified minimum distance c_m (a typical value for c_m is 5).

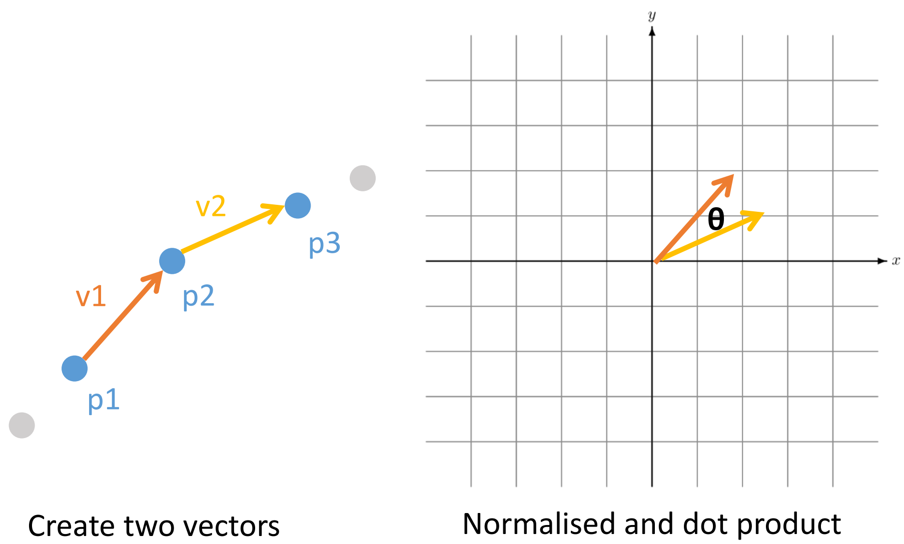


Figure 5.2: Points and vectors visualised

Track Annotation The corner sections resulting from the partitioning process above are further annotated with the addition of the apex, or the corner midpoint vertex. The index i of the midpoint vertex $\mathbf{v}_i$ is given by

$$\forall i, j | (\mathbf{v}_i - \mathbf{v}_0) \cdot (\mathbf{v}_{n-1} - \mathbf{v}_0)_\perp > (\mathbf{v}_j - \mathbf{v}_0) \cdot (\mathbf{v}_{n-1} - \mathbf{v}_0)_\perp, \tag{5.2}$$

where $0 \leq i, j < n$, for a corner section with n vertices, and $\perp$ is the perpendicular operator such that $\mathbf{a} \cdot \mathbf{a}_\perp = 0$.

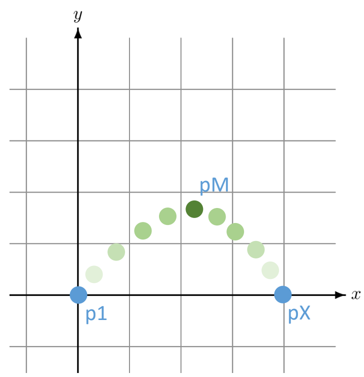


Figure 5.3: Finding the corner mid point
p1 : First point **pM** : Corner mid point **pX** : Last point

Visualisation and Tweaking The partitioning and annotation of tracks is a semiautomated process; a visualisation component was added to the the track splicing tool, to display the partitioning results and bolster confidence in the transformed data. Furthermore, the visualisation helps in the tweaking of generation parameters (c_m, c_t, etc), by showing how changes in these values affect the output (see Figure 5.4).

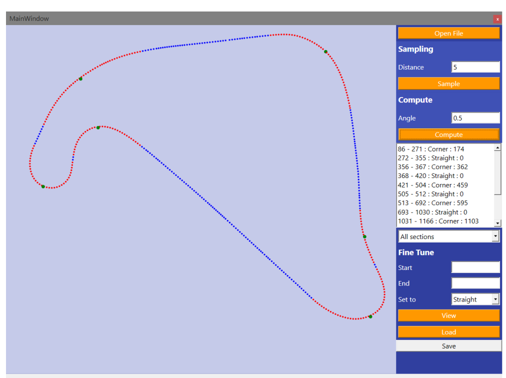


Figure 5.4: Track splicer tool
Blue dots : Part of a straight **Red dots** : Part of a corner **Green dots** : Corner mid point

5.2.2 Persistence of Telemetry Data

Log files containing telemetry data from each user session are inserted into a database management system for offline analysis. An extraction transfer loading (ETL [20]) process (see Figure 5.5) was purposely built, which takes as input a log file and inserts processed data as records into a database. This database is then used to run SQL queries related to the evaluation of the experiment.

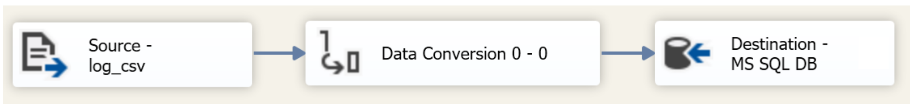


Figure 5.5: ETL process using Microsoft's Integration Services

5.2.3 Spatial Queries

In order for TeAR to determine the closest point on the racing line from the car's current position a spatial querying mechanism is required. Since TeAR provides real-time feedback on how the user is following the racing line, spatial queries are continuously carried out. Therefore, rather than using a linear search, a quad-tree data structure [18] is used to store all the points on the racing line (see Figure 5.6) and accelerate to $\mathcal{O}(\log n)$ spatial queries.

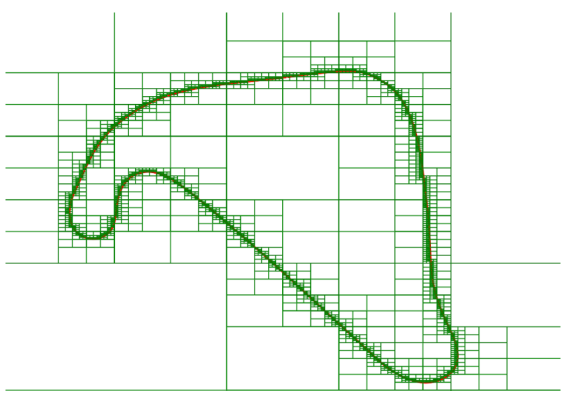


Figure 5.6: Visual representation for part of the quad tree for the Silverstone national circuit

5.3 System Architecture

TeAR is comprised of independent components which pass data to each other in order to select feedback instructions to be presented to the driver. Figure 5.7 illustrates the system architecture of TeAR. The following sections provide an in-depth overview of these components.

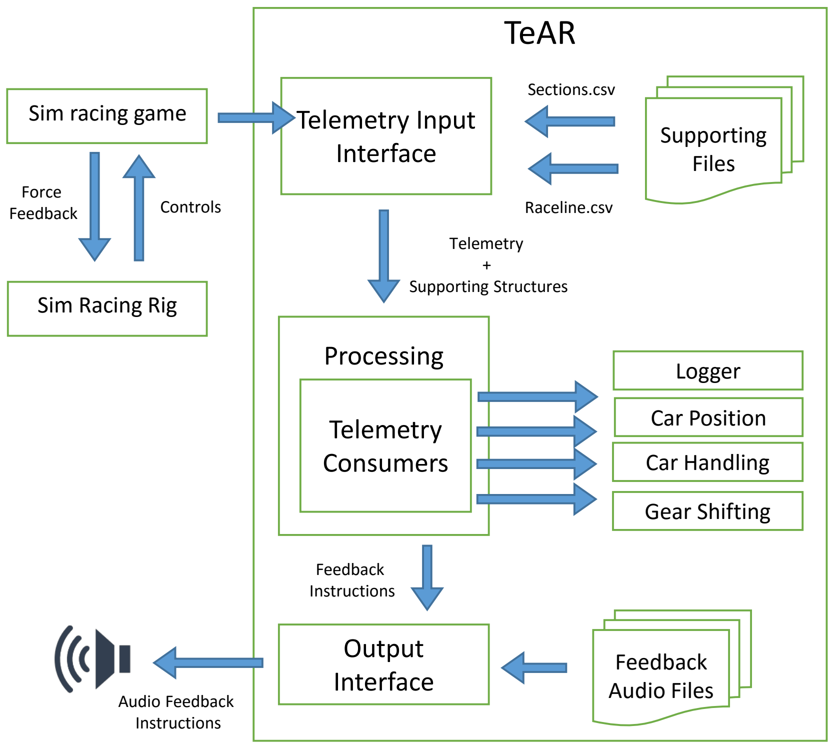


Figure 5.7: Overview of the system architecture components

5.3.1 Telemetry Input Interface

This component handles all data input, either static on a per-track basis or real-time during a user's session. Static inputs include data generated by the track splicing tool. Real-time input is generated by Assetto Corsa which exposes a UDP server for TeAR to connect to and receive telemetry data.

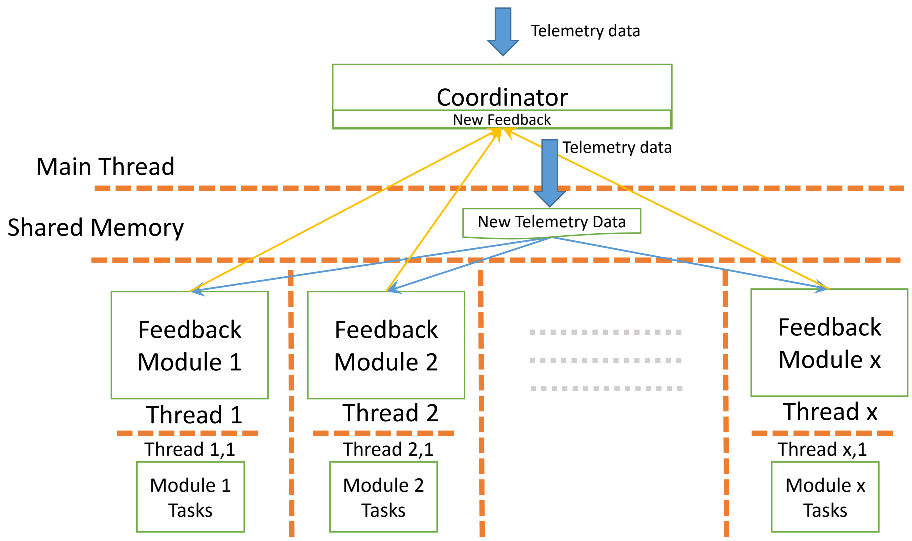


Figure 5.8: Overview of the coordination threading

5.3.2 Processing

Telemetry data is consumed by the processing module, which coordinates a number of sub-modules each consuming the same telemetry data in a different way (e.g. Logger, Car Handling Feedback). These sub-modules run on separate threads and communicate and synchronise with the main processing module using shared memory. Any feedback notification raised by the sub-modules is captured by the processing module, which in turn forwards the message to the output module.

Feedback Processing Sub-modules

Although a number of sub-modules communicate with the processing module, to consume telemetry data, not all contribute towards the final user feedback that the system passes on to the output module. Those that contribute are termed feedback processing sub-modules and their collection comprises a static expert system. The rules and facts that make up this hand crafted expert system are derived from expert knowledge (see Chapter 2).

The feedback processing sub-modules possess a common structure; each module is bound to a telemetry event. These events may be triggered by changes in one or more of the incoming telemetry data values. For example, while a braking event may be tied to a single telemetry datum, a gear-shift event requires examining data related to both the clutch pedal and the shifter.

When an event is triggered, the respective sub-module will start the analysis process related to the respective telemetry information. Eventually, when the corresponding termination event (not necessarily tied to the same telemetry data as the activation event) is triggered, a decision is taken as to whether provide feedback or not, and if so, which feedback (see Figure 5.9).

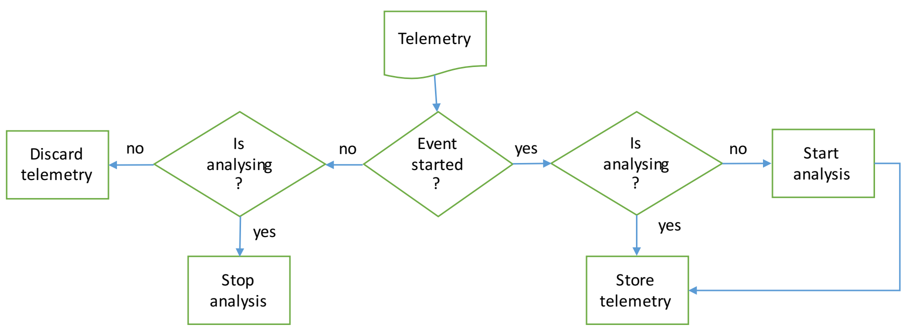


Figure 5.9: Event triggering and stopping flow chart

The system operates using two feedback tiers; initially, at the first tier, only feedback related to the racing line is provided. As the user masters the racing line, the system will switch to the second tier and suggest more advanced feedback.

5.3.3 Feedback Categories

The feedback processing sub-modules each take care of a single skill category. Currently, three different categories are supported: (i) car handling, (ii) car positioning and (iii) gear shifting.

Car Handling

This component monitors for braking and acceleration behaviours, and is able to raise the following feedback suggestions:

- Braking too hard

$$slipratio_f > (15\% + tolerance_f) \tag{5.3}$$

- Braking too light

$$slipratio_f < (15\% + tolerance_f) \tag{5.4}$$

- Losing traction to the drive wheels by applying too much power

$$slipratio_r < -10\% \tag{5.5}$$

The rear and front *slipratio* values are averaged over the period between the activation event and the termination event. The $tolerance_f$ value changes as the user improves; initially it is set to 7% and have been determined through empirical observation.

Car Positioning

This component monitors for any divergence of the car from the racing line, and is able to raise the following feedback suggestions:

- Braking in corner

$$braking * cornering > 0, \tag{5.6}$$

  where $braking$, $cornering \in 0, 1$; zero signifies false, one signifies true.

- Incorrect race line during corner

$$cornering * dist > tolerance, \tag{5.7}$$

where $cornering \in 0, 1$; zero denotes a straight segment, one a corner. $dist$ is the average car distance from the racing line for that section. $tolerance$ is initially set to 10, and is decreased as the user improves. The event triggers when the user transitions from a straight into a corner section ($cornering = 1$).

- Too aggressive during a corner

$$(cornering * slipangle_f) > 8^\circ + tolerance, \tag{5.8}$$

where $slipangle_f$ is the average slip angle for the front wheels.

- Too slow during a corner

$$(cornering * slipangle_f) < 8^\circ - tolerance, \tag{5.9}$$

where $slipangle_f$ is the average slip angle for the front wheels.

Note that all averaged quantities are taken over the period between the activation event and the termination event.

Gear Shifting

This component monitors for user gear changes, and is able to raise the following feedback suggestions:

- Changing gear too soon

$$(8000 * (1 - shift_{up})) + rpm < 8000, \tag{5.10}$$

where $shift_{up} \in 0, 1$; one denotes a gear change, and rpm is the number of revolutions per minute of the car engine.

- Changing gear too late

$$shift_{up} * rpm > 8500, \tag{5.11}$$

where $shift_{up} \in 0, 1$; one denotes a gear change, and rpm is the number of revolutions per minute of the car engine.

- Taking too long to transition from one gear to another

$$time_{neutral} > 0.5s \tag{5.12}$$

where $time_{neutral}$ is the contiguous time spent in neutral gear position.

5.3.4 Output Interface

The final component in TeAR's pipeline is the Output Interface, through which feedback suggestions coming from the Processing module are presented to the user. This module connects to a repository of audio soundbites that map to the input feedback from the previous module. The audio files in the repository were generated using a free online text-to-speech tool [1]. The module does not support concurrent playback of audio feedback by design, since this would overwhelm the user. Furthermore, since feedback is topical, buffering of feedback was intentionally omitted.

5.3.5 Summary

Blah Blah

[1] http://www.fromtexttospeech.com

Chapter 6

Evaluation

This chapter provides an insight into the data collected from the questionnaires and the feedback system logs while also explaining results derived from statistical tests. The chapter is structured as follows: § 6.2 provides an over of the demographic background for the sampled participants. § 6.3 covers test which check the data sets distribution moving on to compare the distribution across the feedback group and base group. § 6.4 goes through determining any difference between the two groups which might have been cuased by the introduction of the feedback system. § 6.5 covers the participants impressions on the experiment and finally conclusive results from this study are presented in § 6.6

6.1 Sim Racing Rig

The rig is made out of various independent components. The steering wheel is a Logitech G25 a pedal set, an H shifter and a bucket racing seat, all mounted on to a home made metal frame.

Figure 6.1: Side view of the racing rig

Figure 6.2: Top view of the racing rig

6.2 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.

6.3 Distribution Tests

From the lap times box plot, one can notice a trend in which lap times improve the more time they use the rig, irrespective of the group assignment. It's worth pointing out the median of the feedback group is lower than the base group's median, except during the last session in which the medians are close to each other. Moreover the participants in the feedback group seem to be less consistent in their lap times as the box plot whiskers and quartiles are more spread out then the ones from the base group.

Carrying out Shapiro-Wilk test for normality for the feedback group and

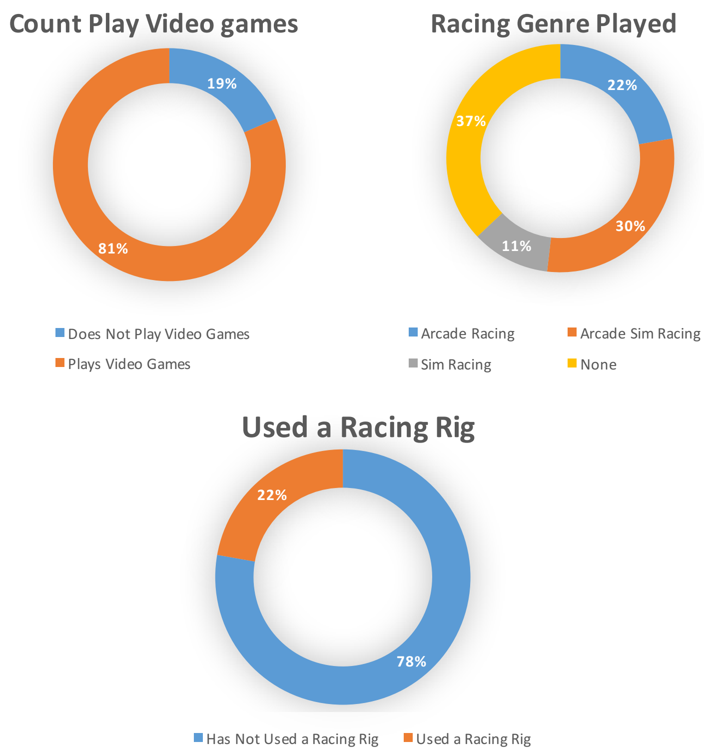


Figure 6.3: Video games experience

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.

6.4 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

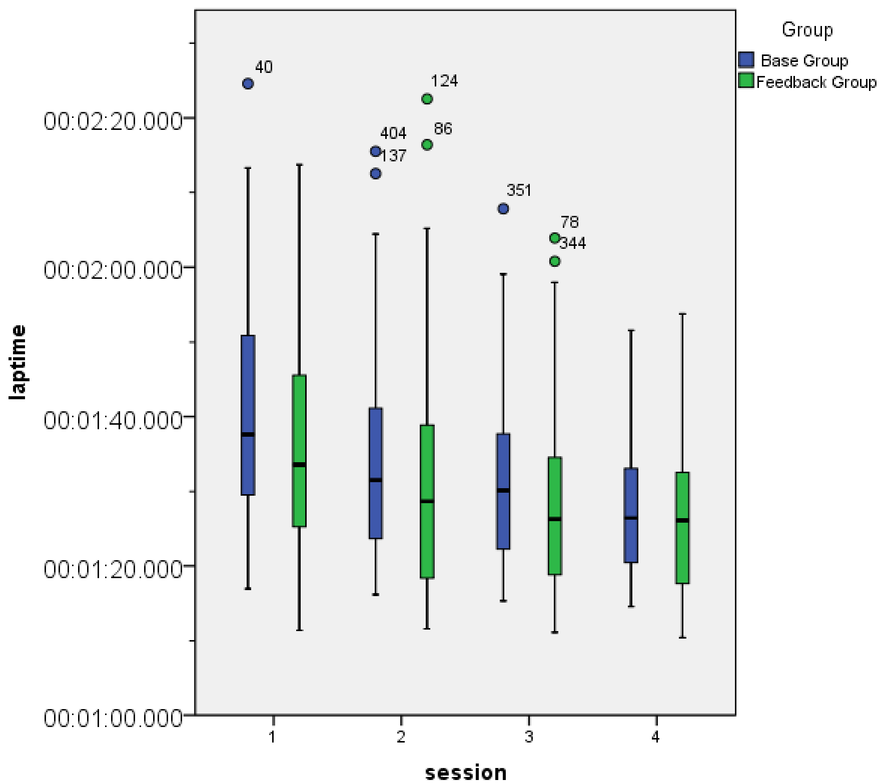


Figure 6.4: Lap times vs session, clustered by group

Tests of Normality

Group		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
LapTime	Base Group	.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 6.5: Shapiro Wilk test results

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

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 6.6: Kolmogorow Smimov test result

Mann-Whitney Test

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: Group

Figure 6.7: Mann-Whitney test result

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.

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 6.8: Mann-Whitney test result for the last the sessions

6.5 Users' Feedback

Users reported an overall good experience, the rig setup was found to be realistic and easy to use. An overwhelming majority of the participants reported having issues mastering the s-bend part of the track, however, they reported that the car and track choice was an adequate one. When the feedback group was asked about the feedback system, they reported to be intelligible, accurate, helpful and somewhat easy to apply the feedback given. Lastly, when asked about if the thought the feedback was intrusive, possible distracting them, out of 15, 5 reported it to be intrusive.

6.6 Discussion

From the post experiment questionnaire one can note that rig setup has been well received, with users enjoying the experiments while also given it a high

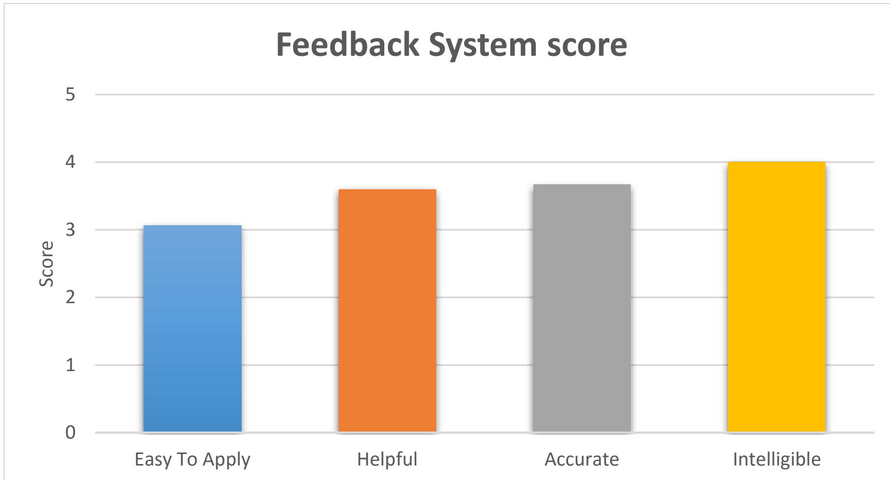


Figure 6.9: Users' Feedback

score for it sense of realism. This suggests that by using off the shelf entry level hardware for the sim racing rig, it is possible to achieve a good level of realisem. the feedback system shows to have potential. the groups start of the same skill level. Both groups show a noticeable improvement from one session to the next session, excluding the last session in which it seems the shorter session might have but extra pressure on the participants' hindering their performance. Furthermore there was not statistical difference during the second session, but during the third session there was. The fact that the feedback group had a lower average lap time it suggest the group managed to get used to the feedback system after the second session and start to follow the feedback instructions during the third session. Lastly the sample is too sample to test for correlation between gaming experience and lap times, as only two players have played sim racing games while the other gamers don't play enough racing games. Same goes for correlation between having a driving licences and being able to the user the rig, as only two unlicensed participants took part, both of which are in the process of obtaining their driving license.

Chapter 7

Conclusion

The skills required to become a good motorsport driver are generally learned through practice, and suggestions provided by more experienced drivers. Our hypothesis for this work is that an automated telemetry-based feedback system can be used to simulate this process and thus, to possibly help novice drivers assimilate this knowledge at a higher rate. For this purpose, TeAR was developed, which using a static expert system, presents auditory suggestions to drivers underlining the driving mistakes they are currently making. An experiment (see Chapter 4) was set up to verify this hypothesis with 27 participants taking part. From the data gathered in this experiment, ...

7.1 Future Work

Following on the results obtained, a number of research avenues which can provide additional insight into the process of learning motorsports skills have been identified. At present, TeAR presents feedback only when the driver is performing something wrong. It would be interesting to determine whether a system which also presents positive feedback, for instance letting the driver know that a previously reported mistake was actually corrected, would lead to any improvements. Furthermore, it is also possible to experiment with a variety of feedback methods, both visual and auditory, on the assumption that different feedback presentation media can lead to changes in the learning rates. Combining both auditory and visual feedback could help in increasing the clarity of the feedback provided. For instance, by visualising the slip ratio while braking, drivers would be able to see how far off they are from the optimal braking slip ratio. The feedback mechanism of TeAR is entirely based on telemetry data provided by the racing simulation software. However, a number of mistakes cannot be directly extracted from this data. For instance, during the experiment it was noted that some of the participants lacked some basic driving skills such as keeping both hands on the steering, not crossing hands while steering and not resting hands on the shifter. This additional information could be collected through the use of a motion tracking camera which directly feeds TeAR.

TeAR is currently intended to help drivers improve their motorsport driving skills. A future direction could also look into the possibility of using TeAR to automate the driving process of a racing car. One possibility is that of using neural nets and fuzzy logic controllers, with both models learning how to drive via the feedback provided by TeAR.

7.2 Charts

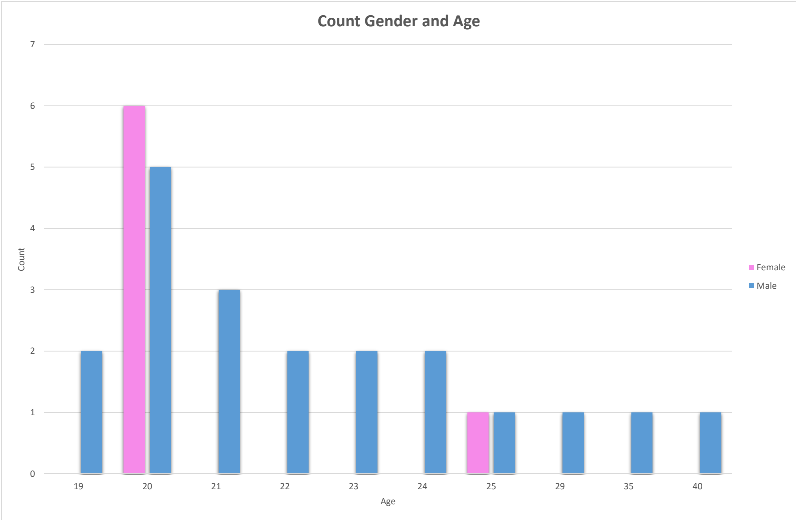


Figure 7.1: Count Participants' gender and age

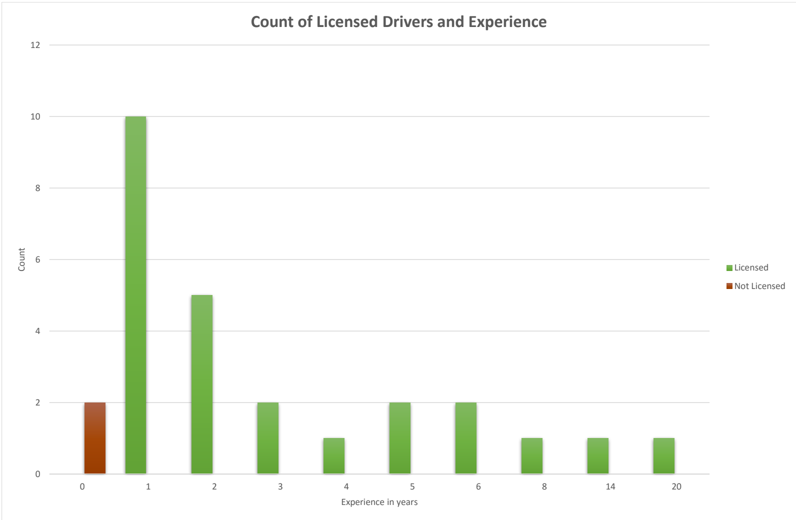


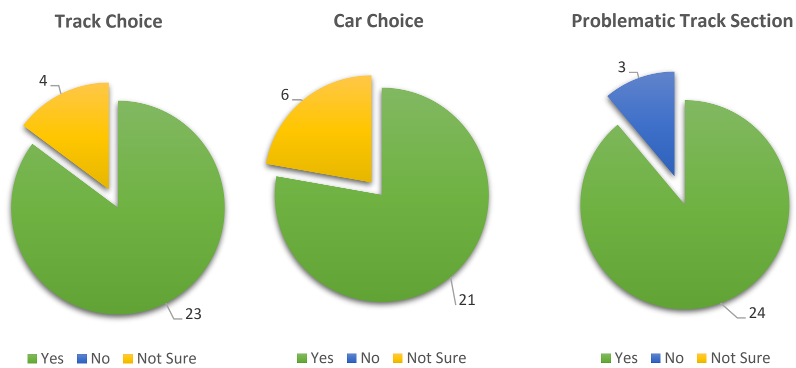
Figure 7.2: Licensed drivers and experience

7.2.1 Questionnaire

Pre study

* Required

1. **Please e**



2. **Age** *

3. **Gender**

   Mark on

   Male

   Female

Figure 7.3: Where the track and car choice adequet?

4. **Do y**

   Mark

5. **How for?**

   In ye

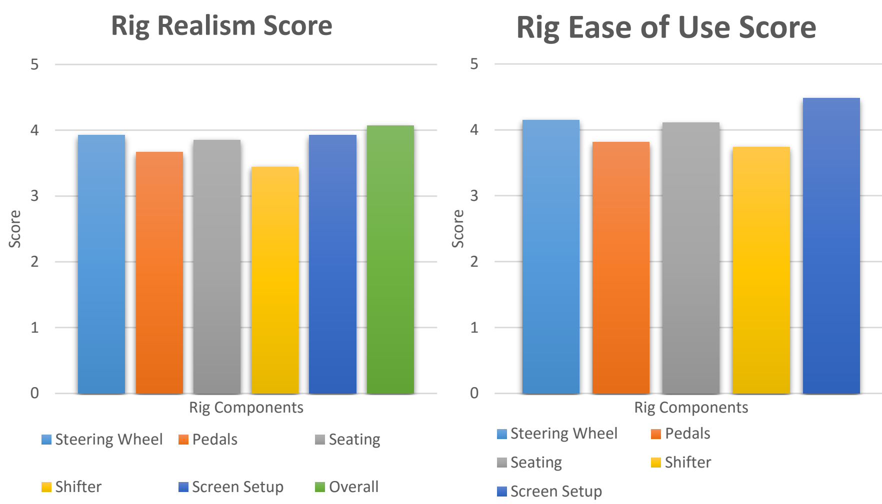


Figure 7.4: How real do these componets feel?

6. **Have you ever been karting ?** *

   Mark only one oval.

   Yes

   No

7. **Ever took part in motorsport events ?** *

   Mark only one oval.

   Yes

   No

8. **What level of motorsport have you taken part in ?**
   Mark only one oval.

   - Casual
   - Single Events
   - Championship

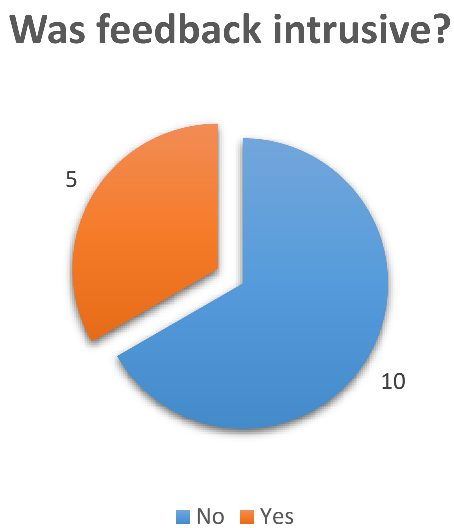


Figure 7.5: Was the feedback intrusive?

9. **Do you follow any mo**
   Mark only one oval.

   - Yes
   - No

10. **Do you play video gar**
    Mark only one oval.

    - Yes
    - No

11. **Do you play any game**
    Mark only one oval.

    - Arcade Racing
    - Arcade Sim Racing (F1 2015, Grid, Forza Motorsport, Gran Turismo, etc)
    - Sim Racing (Rfactor, Live For Speed, Assetto Corsa, Project Cars, etc)

12. **Have you ever used a racing rig?** *
    Mark only one oval.

    - Yes
    - No

Powered by Google Forms

Post Study

* Required

1. **Please enter your ID** *

Rig and Screen setup

How realistic did these components feel?

2. **Steering wheel** *
   Mark only one oval.

	1	2	3	4	5	
Fake	⬭	⬭	⬭	⬭	⬭	Real

3. **Pedals** *
   Mark only one oval.

	1	2	3	4	5	
Fake	⬭	⬭	⬭	⬭	⬭	Real

4. **Seating** *
   Mark only one oval.

	1	2	3	4	5	
Fake	⬭	⬭	⬭	⬭	⬭	Real

5. **Screen setup** *
   Mark only one oval.

	1	2	3	4	5	
Fake	⬭	⬭	⬭	⬭	⬭	Real

6. **Shifter** *
   Mark only one oval.

	1	2	3	4	5	
Fake	⬭	⬭	⬭	⬭	⬭	Real

7. **Any comments ?**

....

....

....

....

....

How easy were these components to use ?

8. **Steering wheel** *
Mark only one oval.

	1	2	3	4	5	
Hard	⬭	⬭	⬭	⬭	⬭	Easy

9. **Pedals** *
Mark only one oval.

	1	2	3	4	5	
Hard	⬭	⬭	⬭	⬭	⬭	Easy

10. **Seating** *
Mark only one oval.

	1	2	3	4	5	
Hard	⬭	⬭	⬭	⬭	⬭	Easy

11. **Screen** *
Mark only one oval.

	1	2	3	4	5	
Hard	⬭	⬭	⬭	⬭	⬭	Easy

12. **Shifter** *
Mark only one oval.

	1	2	3	4	5	
Hard	⬭	⬭	⬭	⬭	⬭	Easy

13. **Any comments ?**

....

....

....

....

....

Simulator

14. **How realistic did it feel ?** *
Mark only one oval.

	1	2	3	4	5	
Fake	◯	◯	◯	◯	◯	Real

15. **Any comments ?**

....

....

....

....

....

16. **Was the track choice adequate ?** *
Mark only one oval.

◯ Yes
◯ No
◯ Not sure

17. **Was there a section of the track which felt more problematic than others ?** *
Mark only one oval.

◯ Yes
◯ No
◯ Not sure

18. **If yes, which one ?**

....

19. **Any comments ?**

20. **Was the car choice adequate ? ***
Mark only one oval.

- Yes
- No
- Not sure

21. **Any comments ?**

Feedback System

22. **How easy was it to apply the given feedback?**
Mark only one oval.

	1	2	3	4	5	
Hard						Easy

23. **Any further comments?**

24. **How helpful was the given feedback?**
Mark only one oval.

	1	2	3	4	5	
Not helpful						Very helpful

25. **Any further comments?**

26. **How accurate was the feedback given?**
Mark only one oval.

	1	2	3	4	5	
Not accurate	⬭	⬭	⬭	⬭	⬭	Very accurate

27. **Any further comments?**

28. **How intelligible was the feedback?**
Mark only one oval.

	1	2	3	4	5	
Not intelligible	⬭	⬭	⬭	⬭	⬭	Very intelligible

29. **Any further comments?**

30. **Was the feedback intrusive (has it effected your concentration) ?**
Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ Not sure

31. **Should the feedback have been more focused?**
Mark only one oval.

- Yes
- No
- Not sure

32. **Any further comments?**

33. **Do you feel the feedback was detailed enough ?**
Mark only one oval.

- Yes
- No
- Not sure

34. **Any further comments?**

Experiment

35. **Do you feel adequate instructions have been give at the start of the session?** *
Mark only one oval.

- Yes
- No
- Not sure

36. **Do you feel adequate time allocations have been given ?** *
Mark only one oval.

- Yes
- No
- Not sure

37. **Any further comments ?**

....

....

....

....

....

Transcript of the audio files

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