A personalized dashboard for sim racing

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Current dashboards for simulation racing games either show too much data that is incomprehensible to the average sim racer, or they fail to provide the user with concrete feedback. In this research, a dashboard is created that provides the user with personalized and concrete feedback based on their driving style. We do this by calculating the perfect braking, turn-in and acceleration points for every corner on a racetrack and compare these with the points where the user actually pressed the brakes, turned the steering wheel or pressed the throttle. This information is translated into concrete feedback and, using multiple visualization methods, we provide the user with a clear overview of where and how to adapt their driving style. Multiple qualitative interviews were conducted to validate the dashboard, revealing its accessibility, user-friendliness, and ability to provide convenient and practical feedback. The dashboard effectively informs drivers of the specific areas and methods to adapt their driving style in order to enhance performance.

Additional Key Words and Phrases: sim racing, personalized feedback, dashboard, racing performance

1 INTRODUCTION

In recent years, the realm of competitive sports has seen a significant shift with the rise of Esports. Where gaming competitions started out on a small scale and with slim to none prizes to be earned, they have now evolved to massive events with millions of viewers and even more millions worth of prize money. In 2022, the League of Legends World Championship managed to peak over 5.1 million viewers, and The International 2021 (a Dota tournament) had a total prize pool of over 40 million dollars [1, 2], proving that Esports are a force to be reckoned with. Many different games have professional players and international tournaments nowadays, and racing games are no exception.

Simulation racing (or sim racing) games form a subgenre of racing games that aim to simulate a realistic racing environment. In the last few years, sim racing has become a popular Esports, especially after the 2020 Formula 1 season got cancelled because of the COVID-19 pandemic, and replaced by a virtual racing season [15]. Just like in any other game and sport, players are striving to be the best, and wish to use all available tools and data to improve their performance. In real life, racing teams - such as Formula 1 teams - have dedicated experts to analyse real-time data from hundreds of sensors in and on the car, in order to enhance the performance of both the car and the driver. These sensors can for example measure acceleration, tyre temperature, g-forces on the car or the angle of the steering wheel [16]. This so-called telemetry data is also available in sim racing games, however sim racers often do not have experts to help them analyse their data and are thus struggling to use it to their advantage [3].

Numerous dashboard solutions have been created that show this telemetry data, like the dashboard shown in Figure 1. These dashboards plot data like speed, what gear the car is in, gas pedal usage and other data points that are of interest over time, to grant the user more insights on the performance of the car. The problem with these dashboards however is that they are all focused on informing a sim racer on the current state of their car, rather than providing the user with feedback on how to improve their driving style. These dashboards also often display raw telemetry data, that is incomprehensible for average sim racers.

Fig. 1. A dashboard using telemetry data

In this research, a dashboard will be created for the sim racing game Assetto Corsa that provides the user with personalized feedback on how to improve their racing performance. This will be done by taking telemetry data from the car out of the game, and translating it into feedback using knowledge gained from a literature review. The dashboard will be aimed towards novice to moderately experienced drivers (<2 years, 2–3 years of experience with sim racing respectively), since these drivers usually lack the knowledge to interpret raw telemetry data and therefore cannot use it to their advantage [3].

2 PROBLEM STATEMENT

There exist numerous dashboards for sim racing, but these suffer from one of two main problems. These dashboards either show too much incomprehensible data or focus on displaying information rather than giving the driver feedback on how to improve their driving style and thus performance.

2.1 Research question

The problem statement leads to the following research question:

RQ: How can a dashboard improve racing performance for novice

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to moderately experienced sim drivers?

This question can be answered using the following sub questions:

RQ1: What are the functional requirements for a dashboard that aims to improve racing performance for novice to moderately experienced sim drivers?

RQ2: What are the non-functional requirements for a dashboard that aims to improve racing performance for novice to moderately experienced sim drivers?

RQ3: How well does the final version of the dashboard meet the requirements?

3 THEORETICAL FRAMEWORK

In this section, the theoretical framework that this research is based upon will be explored. We will discuss the current state of the art of sim racing dashboards, as well as lay the technical foundation on racing performance metrics. Additionally, some dashboard design theory is discussed.

3.1 State of the art

There has not been much research into performance feedback systems for simulation racing. A paper by Bugeja et al (2017). describes the creation of TeAR, a software solution that gives the user feedback in the form of audio cues, based on their performance. However, this paper puts more focus on whether the aspects of serious gaming might be applied to simulation racing, instead of exploring how to give the drivers feedback and what type of feedback to give [6]. In another paper, Shametaj (2023) develops a dashboard for sim racing that translates telemetry data into several Key Performance Indicators (KPI's) that give the driver more insights about their racing style [14]. However, this dashboard does not provide any concrete feedback to the user, meaning that a driver still has to analyse the KPI's themselves in order to find out how they can improve their driving style, and thus improve their performance.

Fig. 2. Raw telemetry data

As mentioned in Section 1 and 2, there exist numerous sim racing dashboards, created by both the sim racing community and tech companies looking to make profit off them. These dashboards often suffer from one of two main problems. On some dashboards, the data displayed is incomprehensible to the average casual sim racer and would only be useful for very experiences racers or experts in the field of telemetry data, such as shown on the dashboard in Figure 2. The data displayed on these dashboards is often raw data, and the enormous amount of data shown at the same time can make the dashboard feel overwhelming. Since the average casual sim racer struggles to decipher the tremendous amount of data, they are also unable to find any insights on their racing performance.

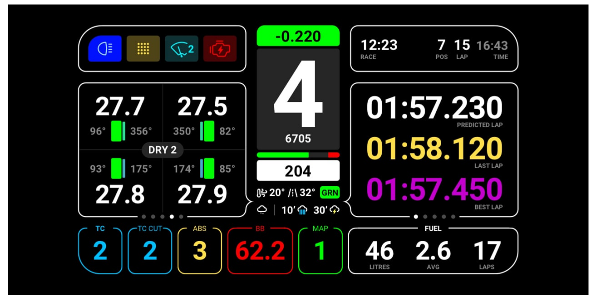

Fig. 3. A dashboard created by the sim racing community

On the other hand, dashboards that pre-process and classify their data in order to improve readability and usability of the dashboard, often fail to give concrete feedback. While these dashboards are often easier to use and read, they only inform the user of the current state of the car. The user still has to apply their own knowledge to the data in order to find out how and where they can improve their driving style. This can be seen on the dashboard shown in Figure 3. Often times, these dashboards also provide the user with live data during a session, while research has shown that users would rather receive feedback on demand [3].

3.2 Performance metrics

In order to create a dashboard that enhances sim racing performance, we must first understand the factors that influence this performance. In this section, we will discuss several important factors that play a role in (sim) racing performance. Our focus will be on the three fundamentals of race driving: the racing line, carrying speed out of a corner and slowing down to properly enter a corner, since according to Lopez (1997) improvement in these areas will reap the most rewards on the track for beginning drivers [10].

3.2.1 Speed. Speed is the first obvious performance factor. The goal of racing is to complete a full lap around a circuit as quickly as possible, and so generally a higher speed on the track means a better performance. The speed of a car can be influenced by a great number of things, including but not limited to: The type of engine the car uses, the type of tyres on the car, the aerodynamics of the car and the inputs the driver gives the car. Since this dashboard will be aimed at improving a drivers performance, we will not take the setup of the car into account in this research, but rather work with the drivers inputs.

3.2.2 Racing line. The ideal racing line is the line a car takes around the circuit that minimizes the time it takes to complete a lap. The line can be seen as a combination of arcs through corners and paths on the straights. The paths on the straights are fairly uncomplicated, as a straight line with minimal steering inputs and fully pressing the gas pedal yields the fastest time on a straight piece of track. In corners however, there are a lot of different approaches. Generally speaking, the fastest line through a corner is to start on the outside and begin the arc through the corner before the track actually starts bending. If you steer into the corner and touch the inside edge of the corner halfway through (also called the apex of the corner), and then the outside edge of the road again on the exit of the corner, you have found the fastest way to take a corner. The reason that this line is the quickest through a corner is that this line generally yields the biggest arc through the corner. Since the greatest arc through a corner requires the car to change direction the least, the maximal cornering speed that the tires can handle before losing their grip is the greatest [5, 10].

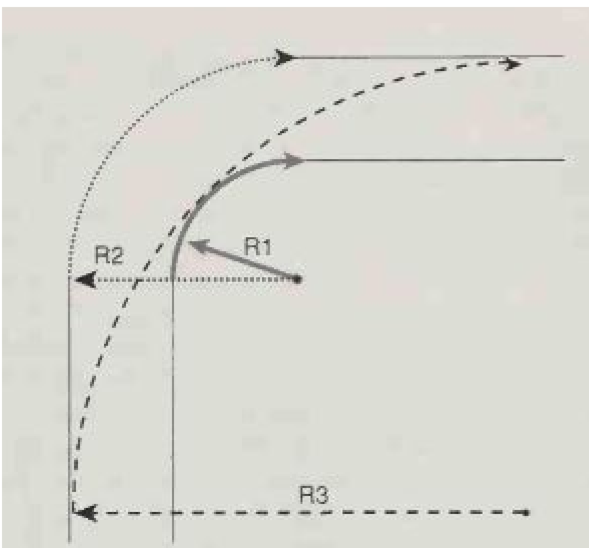

Fig. 4. The racing line visualized. Turning in at R3 yields the greatest arc through the corner and thus the highest average speed. Figure created by Lopez (1997).

3.2.3 Accelerating. Acceleration refers to the usage of the throttle, or pressing the gas pedal. Since around 70% to 80% of a racetrack is spent on the exit of corners and straights, acceleration at the right time in a corner is crucial in carrying the greatest speed out of the corner and onto the following straight. Accelerating on the straight itself is less interesting, as drivers are usually able to use 100% throttle on pieces of track that are (almost) completely straight. The point in the corner where the driver starts to let go of the brakes and starts to use the throttle again, is called the acceleration point. Finding the right acceleration point is important, since applying throttle too early might cause the car to run wide on the exit of the corner, but applying throttle too late will compromise the speed the car carries out of the corner and therefore compromise the speed on the following straight [5, 10, 13].

3.2.4 Braking. Braking refers to the usage of the brakes on the car, which are used to make the car slow down. The brakes are used to make a car slow down to an appropriate speed for entering a corner, as a too high entering speed into a corner will make you lose time since you either have to apply more braking later in the corner, which means you don't carry an optimal exit speed out of the corner, or you might lose control over the car and exit the racetrack. Race drivers will generally use 100% of the car's ability to brake in a straight line when approaching a corner to get the appropriate cornering speed (often referred to as threshold braking), and then use the traction of the tires for a mix of braking and cornering from the point where they start steering, up to the acceleration point. The point where the braking begins is called the braking point, and is a vital point for every corner on the track [5, 10].

3.2.5 Steering. Steering refers to turning the steering wheel of the car, making the tires change direction and thus causing the car to turn into the direction the steering wheel is being turned. Steering is obviously used to get a car through the corners of the track. Generally speaking, having smoother steering inputs will yield quicker times through a corner compared to having more sudden and harder inputs. Like mentioned previously, the grip that the tires of the car have on the surface of the racetrack can be used for accelerating, braking, steering or a mixture of these. The point where a driver starts to turn the steering wheel in order to take a corner is called the steering point, or the turn-in point. This point is also crucial when taking a corner, since an early turn-in point could cause the arc of the car through the corner to be too wide and let the car run off track on the exit of the corner. On the other hand, a late turn-in point could cause the car to take a smaller arc through the corner and slow down more than is required, thus losing time [5, 10, 12].

In Figure 5 a visualization of the performance metrics is given. In this simple right-handed corner, one can identify a braking point, turn-in point and acceleration point, all given on the ideal racing line. It is important to note that the principles of this encoding of the racetrack in different types of input can be applied to every corner, and thus one can find the ideal braking, turn-in and acceleration point for every corner. The only exception to this is when a corner is what is called a 'full throttle corner', meaning that the driver does not have to apply any braking when entering the corner, and can keep using 100% of the throttle all the way through the corner. This could be the case when a corner has such a gentle bend, that the ideal racing line has an arc through the corner that is big enough to allow the car to stay at full speed over that arc.

There are many factors that influence where a perfect braking, turn-in or acceleration point is in every corner. The type of car, the corner entry speed, the current grip of the tires, how much fuel is in the car and many other factors can play a role in this, but these will not be included in this research since we put our focus on novice to moderately experienced drivers. For these types of drivers it is more important to get a good grip of the basics of race driving, rather than putting emphasis on these more advanced factors.

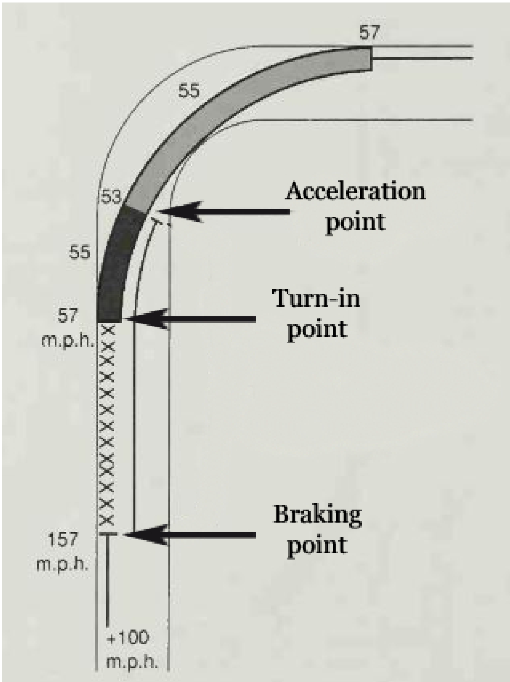

Fig. 5. A corner visualized. The x's represent threshold braking, the dark shaded area represents braking and cornering, the light shaded area represents accelerating and cornering, the straight line represents full accelerating. Based on a figure created by Lopez (1997).

3.3 Dashboard design theory

In this section, we briefly discuss some theory in developing easily understandable and user-friendly dashboards. This theory will be used as the basis for making design choices and determining non-functional requirements. Our main reference for this theory is a book on designing performance dashboards by Eckerson (2011) [8]. Some key principles from their book that we will use in this research are:

- Define clear objectives and identify KPI's that align with these objectives
- Select appropriate metrics to measure performance
- Visualize data effectively and position graphs logically
- Consider use cases and aim for user-friendly interface.

4 METHODOLOGY

This research is conducted for the Esports Team Twente, as part of the University of Twente. The data used in this research was originally gathered for a previous research, but has not been altered in any way and can thus be used again. The data is gathered from the sim racing game Assetto Corsa, and extracted out of the game using a Data Gathering Tool created in previous research [3, 4]. It is important to note that the data used in this research is only from laps driven on the Zandvoort racetrack, therefore some features of the dashboard will be created for this track specifically. The visual part of the dashboard will be created using the Plotly Dash framework for python.

In this research, the design process for the dashboard is done following a framework for designing performance dashboards proposed by Lempinen (2012). This framework proposes an iterative, agile development process for a performance dashboard consisting of 3 phases, each focusing on a different challenge in the design process [9].

The first phase of the design process is focused on the challenge of what to measure. In this phase, we will decide what metrics and KPI's will be displayed on the dashboard and what data we need to capture in order to retrieve this information. We will do a literature review for the purpose of deciding what information we want to display on the dashboard, as well as looking at what data is available to find out the best available information to display. Since we will use data that is already collected, we will not have the possibility to alter the Data Gathering Tool to extract more or different data. We can only use the available data points and combine these in order to find new information. In this phase we will also find the technical and non-technical requirements from which we can answer **RQ1 & RQ 2**

The second phase of the design process focuses on where and how to capture the data required. This will not form a challenge during this research, since the data has already been captured and is ready to use. The data is gathered from driving a McLaren MP4-12C GT3 around the Zandvoort circuit in Assetto Corsa. The data is exported from the game in the form of 5 separate .csv files containing data on the session itself, the car, the laps, the inputs and the tyres. For this research, the data is imported into a python project in the form of a Pandas dataframe, from where the data can easily be read and manipulated.

The third phase of the design process will focus on how to deliver performance information to the users. This phase will be centred around designing the look and feel of the dashboard, as well as finding clear ways to visualize the data. In this phase, the user interface of the dashboard is designed and evaluated.

Ultimately, the final design of the dashboard was validated and **RQ3** was answered using a qualitative validation in the form of one-on-one interviews. We interviewed 2 sim drivers, one novice and one moderately experienced. The interviews were conducted with a semi-structured format and the questions were centred around the usefulness and readability of the feedback, as well as the user-friendliness of the dashboard.

5 DEVELOPMENT OF THE DASHBOARD

In this section, we will elaborate on the development of the dashboard according to the phases mentioned in the previous section. Lempinen (2012) proposes an iterative and agile approach to dashboard design, so considering the time limit for this research, we chose to have two iterations of the design process.

5.1 First iteration

5.1.1 Requirements. Based on the theoretical framework laid out in section 3.2, and the methods stated in the Methodology section, we can create a list of initial requirements with which we will start the first design iteration.

Functional Requirements:

- The dashboard must provide personalized feedback based on the user's driving style.
- The dashboard must provide feedback on braking, turn-in and acceleration points.
- The user must be able to see where they can improve and where they are performing well from the provided feedback.

Non-functional requirements:

- The user should be able to find all relevant information on the dashboard in two clicks from the main screen.
- The dashboard should have a consistent layout.
- The dashboard must be publicly available.

5.1.2 Phase one. In the first phase of the design process, we looked at what information we wanted to display on the dashboard. Using the theoretical framework laid out in Section 3, and especially the performance metrics explored in session 3.2, we were able to find some KPI's that can tell us a lot about how a driver can improve. Like mentioned in Section 3, anyone can keep their foot on the gas and let the car go in a straight line, but in the corners where the driver has to give a lot of inputs to the car, is where the most time can be gained and lost.

That is why we wanted our dashboard to display hints to the user about how far away they were from the perfect braking, turn-in and acceleration points for each corner. If for example a driver is constantly braking too early into turn 1, the dashboard could display a simple message like 'brake later in turn 1'. In this first iteration of the dashboard, we wanted to calculate how far away the user was from the ideal braking, turn-in and acceleration point of each corner. This information can be shown to the user as the points where they were the furthest away from the ideal points, but also show the points on the track where the user was doing the best (braking, steering or accelerating very close to the ideal point). We show both of these since previous research has concluded that users would like to receive both positive and negative feedback [3].

5.1.3 Phase two. When we knew what we wanted to display on the dashboard, we could get the required data from the data sets. First, we had to determine for every corner what the ideal braking, turn-in and acceleration point is. We did this by following a Track guide that provides plenty of visual cues to find these points, as well as a video of one of the fastest laps ever on the Zandvoort circuit in Assetto Corsa using the McLaren Mp4-12C GT3, where one can clearly see the usage of the throttle, brakes and steering wheel [7, 11]. Important to note here is that corner 4, 5 and 13 of the Zandvoort circuit do not have braking and acceleration points since they are full-throttle corners. Using the fact that there is a lap position variable in the data, that shows how far into the track the car currently is on a scale from 0 to 1, we know exactly when a car is in a certain part of the track. With this information we can deduct when a car is in a certain corner, and using the input data we can tell when the driver presses the brakes, turns the steering wheel or presses the throttle. We can then calculate the distance between the ideal braking, turn-in or acceleration point, and the actual point where the driver used this input.

We did this by creating a Pandas dataframe containing all the data of one session on the braking, steering and acceleration inputs, as well as the in-game coordinates of the car, the lap position and the lap count. This data is combined from multiple of the different .csv files, and is synchronized by the timestamp of the data. We calculate the distance between each user input point and ideal point in the following way: First we found a range of lap position values for each corner. Then, inside this range of data points, we found where the value of gas, brake or steer passed a certain threshold. The gas and brake input values are scaled from 0 to 1 (where 0 means not pressing the pedal at all and 1 means fully pressing the pedal), and appropriate threshold values were found to be 0.25 and 0.35 respectively. The steering input values are in degrees, and are positive when steering to the right and negative when steering to the left. Threshold values for the steering input were found to be -35 degrees or +35 degrees. When an input value crosses its respective threshold value, we use backtracking to find the exact point where the increase to the threshold started. This point is used as the braking, turn-in or acceleration point.

The distance between the actual point and the perfect point is then calculated by the formula:

$$Distance = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

Where (x1,y1) and (x2,y2) are the coordinates of the actual and perfect input points respectively. It is important to note here that we also check whether the lap position value of the actual point is smaller or greater than the value at the perfect point. If it is greater, the input was given later on the track and feedback needs to show that the user has to use this input earlier, and vice versa.

We repeat this process for every lap and derive the average distance over all the laps in the session. We do not include the first and final lap of the session, as these laps are not a good representation of an actual racing lap. The four points with the greatest average distance (so the four points where the driver is furthest away from the ideal point and can theoretically improve the most) are shown on the dashboard, as well as the four points with the lowest average distance (so the four points where the driver is closest to the ideal point).

5.1.4 Phase three. With all the data in place and all the required functions created to find the best and worst points for a driver, we could start with the first user interface design of the dashboard. Since there are two categories of information that we want to show (best and worst points), we will divide the dashboard in two columns containing information about these categories respectively. The information will be displayed using icons that show in which corner the user can improve on what type of input. Since it is difficult to convey all the information of 'brake later in turn 1' in one small and comprehensible icon, we decided to also put a small text next to the icon giving further explanation. To make sure that the user will first see the points that they can improve on, we decided to show these in the left column, with the good points of the user consequently being placed on the right. We also decided to show the points that can be improved on in red, and the good points in green, to emphasise on the ideas of good and bad with these points, as well as to create some contrast in the colours used. A first version of an icon can be seen in Figure 6.

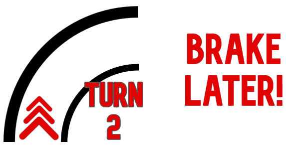

Fig. 6. An example icon showing the user should brake later in turn 2.

5.2 Second iteration

After having created a first version of the dashboard, this version was discussed and evaluated with the supervisors of this research. Based on these sessions, some improvements to the dashboard were suggested with which we could start the second iteration of the design process.

5.2.1 Requirements. Based on these improvements, more functional and non-functional requirements were found that we can add to the list mentioned in section 5.1.1.

New functional Requirements:

- The dashboard must provide general information about the session.
- The user must be able to recognize the corners provided in the feedback.
- The user must be able to see how much they need to adapt their driving style according to the feedback.

New non-functional requirements:

- The dashboard should not overwhelm the user with too much information.

5.2.2 Phase one. In this section design iteration, we wanted to make the feedback provided by the dashboard clearer and convey more information, since a novice or moderately experienced driver might not know exactly what turn on the track turn 8 is. To solve this issue, the dashboard should show more visual cues to make it clear to the user what corner an icon refers to. The best visual cue we can provide for this is a screen capture of the corner out of Assetto Corsa, with an indication of where a braking zone, turn-in or acceleration point is. The inspiration for these screen captures was taken from a Zandvoort track guide by Cardo Racing School [7].

Beyond that, the icons displayed on the first version of the dashboard only tell the user that they for example have to brake later in a certain turn, but do not give the user any indication of how much later they have to press the brakes. To resolve this issue, we want to show the user a simple graph of the corner with their average braking, steering or acceleration point on it, as well as the ideal braking, steering and acceleration points. This way the user can see how far from the ideal point they are and how much they need to adapt their driving style in order to improve their performance.

Furthermore, we found that the dashboard should also display some general information about the session. Since data is loaded into the dashboard per session, it makes sense to show information about the session, so the user gets a better understanding on how to interpret the feedback given. This general information will include what track was driven on, what car was driven, the best lap time in the session, the average lap time in the session and the number of racing laps in the session. The number of racing laps excludes the first and last lap of the session since these are usually not representative racing laps. For this reason, they are also excluded from the rest of the data.

5.2.3 Phase two. We gathered the visual cues as screen captures from the Assetto Corsa game using the built-in camera mode. Once enabled from the developer options, the camera mode allows us to freely roam a circuit in the game and take screen captures of every corner where we can clearly show the ideal braking, steering and acceleration points.

In order to create a graph that shows the ideal input points and actual input points of the user required some data manipulation. We first managed to plot the entire circuit by plotting the world coordinates of a car driving around both the inner and outer edge of the circuit in a scatter plot. Using this scatter plot we managed to find a range of x and y values for every corner such that when plotting only these values, the graph only shows this corner. This is important since working with multiple graphs that plotted the entire circuit gave rise to significant performance issues, but now we could work with graphs that show only a specific corner. We calculated the coordinates of the average braking, turn-in and acceleration points by taking the average of the points we found for calculating the distances mentioned in section 5.1.3, and overlapped these together with the ideal points to create a graph like figure 7. These graphs were also created for the corners and points where the user is closest to the actual point, and also a simple legend was

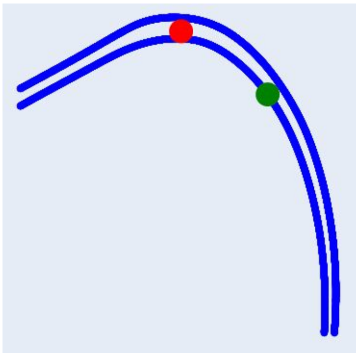

Fig. 7. An example graph showing the ideal and the actual acceleration point for corner 6.

created indicating that the red dot is the user's actual input point, and the green dot is the ideal point.

5.2.4 Phase three. We decided to put the newly created screen captures and graphs in a pop-up that opens when the user clicks one of the icons. So for example when the user clicks the icon 'accelerate later in turn 6', a pop-up opens that shows an in-game screen capture of turn 6, that also points out where on the track the acceleration point is, as well as the graph that can be seen in figure 7 displaying where the ideal and actual acceleration point are in the corner. We decided to show this information in a pop-up to keep the dashboard clear and readable, since immediately showing eight of these screen captures and graphs would make the dashboard display so much information at the same time that a user might be overwhelmed. The example pop-up discussed in this section can be seen in Figure 8.

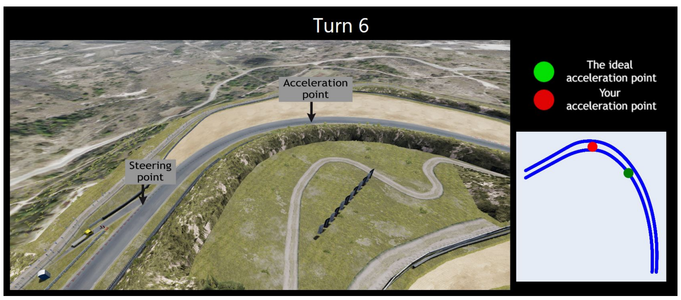

Fig. 8. An example pop-up showing the in-game capture and graph displaying the input points.

Additionally, another column was added to the dashboard to display the general session information. This information is displayed in a simple way under one another. We also show the layout of the track in this column. Lastly, some of the icons were updated to show a corner bending to the left if the corresponding corner on the track is a left-handed corner, instead of all the icons showing a corner bending to the right. The final version of the dashboard can be seen in Figure 9.

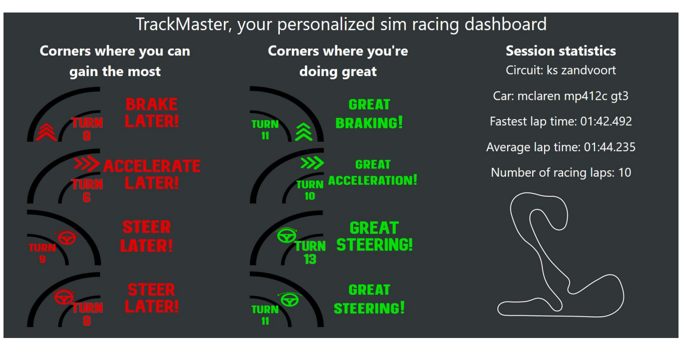

Fig. 9. The final version of the dashboard.

6 EVALUATION

To evaluate the final version of the dashboard, multiple qualitative interviews were conducted. One interview was conducted with a novice sim driver and one with a moderately experienced driver. These interviews followed a semi-structured format and contained questions on the feedback given by the dashboard and the usability of the dashboard itself. Before starting the interview, the participants were given a few minutes to try out the dashboard for themselves and form an opinion.

Questions used in the semi-structured interviews:

- What do you think of the overall look and feel of the dashboard?
- Do you feel the feedback given by the dashboard is useful and appropriate?
- How user-friendly did you find the user interface?
- How did you interpret the visualizations and data presented in the dashboard?
- How can this dashboard impact your racing performance?
- Is there any important information missing on the dashboard?

6.1 Results

After analyzing the interviews we came to the following conclusions. Overall, the dashboard was found to be easy to use and the feedback to be very informative and useful to quickly improve lap times. The look and feel of the dashboard was described as "Accessible and very easy to use, even if you're not yet familiar with the track". When asked about the feedback given by the dashboard, the interviewees mentioned they liked the feedback on the braking, steering and acceleration points since "I feel like these are the 3 basic skills you need to get right first". Furthermore, both interviewees mentioned that the visualization methods used on the dashboard helped give a better understanding of the feedback, "The icons give a first indication ... the picture in the pop-up helps you recognize the corner even better".

Moreover, the interviewees would both want to use the dashboard since they feel it can help them improve quickly. They made this clear by saying "Especially on a track you're not familiar with yet, this dashboard can save you a lot of time finding good braking, steering and acceleration points.", and "I think that you can improve way quicker with this dashboard than by just driving around on your own". Both interviewees also liked that there is positive and negative feedback on the dashboard, since "Rather than just knowing where you have to improve, it's also good to know where you can keep doing the same thing".

Lastly, it is also important to take into account the more critical feedback received in the interviews. One of the participants mentioned that without explanation, they would not have found out that the icons were clickable. "At a first glance, it looks like there is not much to the dashboard since you don't immediately see that the icons are clickable." Additionally, both interviewees mentioned that they would very much appreciate a function to compare different sessions with each other. "If you can compare different sessions, you can immediately see if you actually improved in the corners that you tried to focus on, based on the first feedback given by the dashboard"

7 CONCLUSION

In conclusion, a dashboard was created that aims to improve sim racer's performance by giving personalized and concrete feedback in accordance with the functional and non-functional requirements found in section 5. These requirements were found as a combination of the theoretical framework laid out in section 3, best practices and further sim racing and dashboard research. The functional requirements split the dashboard in 3 columns, the points where the user can improve the most, the points where the user is closest to a theoretical best lap and the general information on the session. The feedback points for the user grant them information about in what corners they can improve and how they should adapt their driving style in order to find this improvement. This is done using screen captures from Assetto Corsa as well as a graph showing a corner and the user's input points together with the ideal input points. For the evaluation of the dashboard, qualitative interviews were conducted with 2 novice to moderately experienced sim drivers. In these interviews we found that the dashboard is accessible and user-friendly, and that the feedback provided can help drivers see exactly where and how much they need to adapt their driving style. Thus we can conclude that this dashboard provides sim racers with proper feedback to improve their driving performance, and that this dashboard with its functional and non-functional requirements might form a foundation for future personalized sim racing dashboards.

8 RECOMMENDATIONS

8.1 Limitations

While this research has created a dashboard that was found to be accessible and useful, it is important to acknowledge certain limitations that may have impacted this research. First of all, the evaluation part of this research is very limited due to time constraints. We originally intended to use a quantitative evaluation in the form of a survey with multiple novice to moderately experienced sim drivers as participants. Unfortunately, due to time constraints we had to resort to a couple of interviews in order to validate the dashboard. Also, the current ideal braking, turn-in and acceleration points are gathered by hand, based on the track guide and video, and might not be completely accurate since we had to translate this information into the coordinate system that Assetto Corsa uses ourselves.

8.2 Future work

For future work, the next step is to generalize this dashboard, so it can be used for any racetrack. This could be done by manually getting the ideal points for every corner and applying those within this dashboard, or a machine learning algorithm could be applied to a racetrack to automatically find all the turns on the track and their ideal points. A machine learning algorithm could also be applied to the finding of the user's input points, which is currently done by backtracking after the input crosses a certain threshold value. Furthermore, a more advanced version of the dashboard might include adaptive braking, turn-in and acceleration points based on how much fuel is in the car, the current grip that the tires have and possible other factors. Moreover, some other features like the comparison between separate sessions could be implemented to grant the user more insights on how they are improving. Finally, future work could also include experiments that test if this dashboard actually improves performance, especially when compared to information focused dashboards.

REFERENCES

[1] 2021. The International 2021 - Liquipedia Dota 2 Wiki. https://liquipedia.net/dota2/The_International/2021

[2] 2022. Most Watched Esports Games in 2022. https://escharts.com/news/most-watched-esports-games-2022

[3] Daniël Assies. 2021. Developing a Smart Telemetry Feedback System for Sim Racing. http://essay.utwente.nl/87322/

[4] Daan Assies. 2022. https://github.com/DaanAssies/DGT.

[5] Ross Bentley. 2011. *Ultimate speed secrets: The complete guide to high-performance and race driving.*

[6] Keith Bugeja, Sandro Spina, and Francois Buhagiar. 2017. Telemetry-based optimisation for user training in racing simulators. *2017 9th International Conference on Virtual Worlds and Games for Serious Applications, VS-Games 2017 - Proceedings* (10 2017), 31–38. https://doi.org/10.1109/VS-GAMES.2017.8055808

[7] Cardo Racing School. 2021. Track Guide | Zandvoort - CRS - Sim Racing Resources. https://cardoracing.com/resources/track-guide-zandvoort/

[8] Wayne W. Eckerson. 2011. Performance dashboards : measuring, monitoring, and managing your business. (2011), 318. https://www.wiley.com/en-nz/Performance+Dashboards%3A+Measuring%2C+Monitoring%2C+and+Managing+Your+Business%2C+2nd+Edition-p-9780470589830

[9] Heikki Lempinen. 2012. Constructing a design framework for performance dashboards. *Lecture Notes in Business Information Processing* 124 LNBIP (2012), 109–130. https://doi.org/10.1007/978-3-642-32270-9{_}7/COVER

[10] Carl Lopez. 1997. *Going faster!: Mastering the art of race driving.* Bentley Publishers.

[11] Emanuele Petri. 2016. Assetto Corsa - Mclaren Mp4-12C GT3 @Zandvoort - 1.35.717 [WR] - YouTube. https://www.youtube.com/watch?v=TNrwQ5APnL4&t=61s

[12] Claude Rouelle. 2019. Key Performance Indicators: Steering smoothness | OptimumG. https://optimumg.com/key-performance-indicators-steering-smoothness/

[13] Claude Rouelle. 2021. On the Throttle | OptimumG. https://optimumg.com/on-the-throttle/

[14] E. Shametaj. 2023. Sim racing : a performance-enhancing dashboard. (2023). https://purl.utwente.nl/essays/94366

[15] Elizabeth Tudor. 2021. The Emergence of eSport During Covid-19: How Sim Racing Replaced Live Motorsport in 2020 - Repository of Open Access Research (RoOAR). *Journal of Motorsport Culture and History* (2021). https://ir.una.edu/work/ns/c5f2c787-181b-4eaa-8d60-51d530574b23

[16] Jim Waldo. 2005. Embedded computing and formula one racing. *IEEE Pervasive Computing* 4, 3 (7 2005), 18–21. https://doi.org/10.1109/MPRV.2005.56