Designing a detailed telemetry dashboard for sim-racers

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Fig. 1. Online race in Assetto Corsa

Racing Simulators are games that simulate the real-world racing environment and physics. Simulated cars and tracks generate vast quantities of telemetry data that can be analyzed to improve driving performance, much like the real world. While industry-standard telemetry systems exist (used by professional esports teams), such as MoTeC i2 and McLaren ATLAS, they are suffer from over-complexity in design and require technical knowledge that a solo driver might not possess. This paper aims to propose standards for a detailed data-analysis tool (dashboard) tailored towards not only moderately-experienced sim-drivers but also data-analysts in small/semi-professional teams by deriving functional and non-functional requirements. A preliminary dashboard was developed as part of the research and evaluated against a group of participants for validation. The goal is to bridge the gap between the technical analysis in professional esports and rest of the community by providing standards for a dashboard tool that focuses on usability and ease-of-access.

Additional Key Words and Phrases: sim-racing, dashboard, telemetry, e-sports, data analysis, usability, UI design, UI/UX

1 INTRODUCTION

Sim-racing or simulation racing refers to the concept of virtual racing usually taking place on gaming softwares that attempt to replicate the real-world environment of motor-sports [7]. There has been a rise in popularity of such games during and after the Coronavirus pandemic; much of this surge is also attributed to the success of professional motor-sport competitions like Formula 1 with popular drivers like Max Verstappen and Lando Norris streaming sim-racing into the mainstream and gaining massive viewership [4]. With various well-known professional motor-sports drivers competing in virtual sim-racing championships [5], the casual drivers of the community are also inspired to participate in competitive racing and seek superior performance.

Telemetry is the remote monitoring and collection of measurement data; variety of sensors are attached to the car to record data on multiple parameters such as, gear shifts, steering angle, engine performance, split times etc. [3, 9]. As with various motor-sports championships, analysis of telemetry data is essential to improve driving and racing performance in racing simulations [2]. Large amounts of data is obtained through telemetry and provide analysis and visualisation opportunities to improve overall lap and driver performance. Similar data is also available and can be extracted from the simulator games to formulate different metrics for analysis.

There are major esports organizations in sim-racing, such as Team Redline and Williams E-Sports, that have the financial and personnel resources to utilize real-life telemetry systems for performance insights. However, the majority of sim-racers and small teams lack technical knowledge and lack access to data-analysis teams in order to interpret and gain insight into performance metrics. "*Telemetry is hell if you don't know what you are doing*" - as explained by the Head

TScIT 39, July 7, 2023, Enschede, The Netherlands

of Vehicle and R&D at KUNOS Simulazioni (creators of Assetto Corsa), trying to interpret complex telemetry without extensive knowledge may even lead to more harm than good [1].

The goal of this paper is to bridge the aforementioned gap and provide comprehensible telemetry-analysis to the racers and teams that seek to improve their performance. This was realized via deriving standards for a data-analysis tool tailored towards sim-racing. The following research questions are used to guide this process:

RQ1: What are the functional requirements for a telemetry dashboard with the aim to increase sim-racing performance while retaining simplicity?

RQ2: What are the non-functional requirements for a telemetry dashboard with the aim to increase sim-racing performance while retaining simplicity?

RQ3: How to realise these specifications using dashboard design and best-practices?

The paper also comprises of developing a preliminary dashboard, which along with user tests and an accompanying feedback survey to validate the research questions.

2 CURRENT STATE AND RELATED WORK

This section covers existing solutions and research in sim-racing telemetry analysis softwares.

This study by Shametaj [18] explores the requirements for a sim-racing dashboard that is geared towards novice and moderately-experienced sim-racers with the aim to better their performance. As a conclusion, a dashboard prototype is also presented which attempts to visualize key performance metrics. Since, this study was also part of the EsportsLab at University of Twente, the construction of the preliminary dashboard borrowed much inspiration from Shametaj's design.

VRSTelemetryLogger is a telemetry tool offered by Virtual Racing School exclusivel for the iRacing simulator [22]. Offered as a subscription service, it consists of various tiers each containing different data packs. Data packs are car-track combinations comprising of ideal racing techniques and sectors to compare against user's driven lap. Using the free subscription, VRS shows basic information such as stints, setup and split times for each driven session as 'Driver Statistics' with opportunity to compare your lap with your own data, your teammate or data packs (if available in the subscription) as 'Driving Analyzer' which delves into more advanced statistics and metrics to analyze two sessions [13]. The Driving Analyzer provides side-by-side video comparing parts of laps with a time-delta, speed trace, line difference against another driver or data-pack [12]. While being a highly valuable tool, the VRS system is locked behind a paywall making it less-desirable for the sim-racing community.

Simply called the Telemetry Tool, it is a community-made dashboard tool by Iko Rein who updates the tool frequently [14]. It supports multiple games and simulators, and has acquired praise on the Race Department, a community forum for sim-racers [15]. The software relies on a detailed dashboard with telemetry for forces, differentials and input, track-maps and statistics. Additionally, on his YouTube channel Rein uploads videos explaining his tool and providing tutorials for different use-cases [11]. As mentioned on the tool's website, Telemetry Tool is currently free-to-use but provides optional licensing options to support the development, and gain access to exclusive features in the future.

Sim Racing Telemetry (abbreviated as SRT), a utility tool on Steam [20] to review and analyze telemetry data from sim-racing games. UNAmedia, the developers of SRT, describe it as an essential tool for the esports sim-racing community [21]. It also supports multiple games with access to all telemetry data generated by each game. SRT provides many essential features like interactive charts and channels, laps comparison, interactive track map and options to share and export data as CSV. However, while being a very versatile tool SRT suffers from over-complexity and cluttered user-interface. Thus, the SRT design was an inspiration for both implementing functionality and avoiding over-complexity pitfalls.

3 METHODOLOGY

The research project is in collaboration with the EsportsLab, e-sports research group, at the University of Twente specifically for the racing sim, Assetto Corsa.

This research focuses on designing and developing the dashboard prototype which, consequently, provided conclusions to the proposed research questions through traditional requirements engineering. A modified Waterfall methodology was utilised for this research project due to the model's alignment with the sequence in which the research questions are posed (analysis, design and development). The exact planning is displayed in the GANTT chart (See Figure 2).

According to the Waterfall methodology, a project is structured in a linear and sequential manner, with each sequence being referred to as a 'phase' [19]. The phases: analysis, design, development, testing and verification (and/or maintenance), with analysis and design being the most essential ones, with respect to this study. The model realises phases completion with deliverables, providing an accountable review system for each phase.

Requirements Engineering is the process of deriving detailed requirements from stakeholders' desires and vision and using them as a base for the development process [10]. As part of the analysis phase, requirements were elicited and specified through literature review and examining professional counterparts. Upon delivering the requirements and hence answering **RQ1** and **RQ2**, a design phase was initiated wherein dashboard design theory, and analysis of best-practices was used to deliver a lo-fi prototype.

Next, the lo-fi prototype was transformed into a working preliminary dashboard with connection to the data-gathering tool [6] provided by the EsportsLab as part of the development phase.

The final preliminary dashboard was evaluated through user tests and a feedback survey against multiple participants for multiple characteristics like usability etc. The results of the survey were used to validate **RQ3**.

4 RELEVANT METRICS

In this section, we identify and define the mentioned and other key sim-racing metrics that provide insight into driver-performance and can potentially help sim-racers to set the fastest lap possible. The metrics described below were partly derived from Jorge Sergers' book on racecar data acquisition [17].

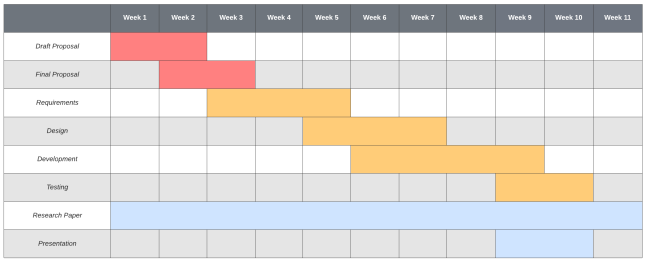


Fig. 2. GANTT Chart - Planning

4.1 Engine RPM

Revolutions Per Minute is an essential statistic for the performance of a motor-vehicle; represented as a line graph it accurately records changes and spikes in engine revolutions. These spikes and sudden changes in engine RPMs when coupled with gear activity can reveal shifting habits of a driver and provide points of improvements. Moreover, comparing engine spikes with the location on the track, one can reveal the spots where the driver may be struggling for traction (static friction between the tyres and the track which keep the vehicle from sliding).

4.2 Throttle

Throttle position refers to the percentage of throttle (letting air in) to the engine, or simply put how hard the driver is pressing on the accelerator (the throttle pedal). Analyzing throttle activity can provide insight into driver issues, identify and rectify mistakes on track. A smoother throttle activity provides better corner turning and alleviates loss of traction [16].

4.3 Brake

Analysis for brake pedal position is very similar to throttle analysis. The ability to reach maximum brake pressure allows the driver to delay the braking phase and consequently improves lap times [8]. However, there's also emphasis on how smooth the driver releases the brake when encountering a corner (entering), brake points and scenarios like trail-braking. Thus, identifying spikes in brake input can be vital for improving a lap.

4.4 Steering

Steering Angle is an essential driver activity metric. It is simply the angle at which the steering wheel is turned which when subjected to analysis can help rectify many mistakes (struggling for traction) and issues as well as provide points of improvements. The graph for the steering angle when combined with tyre slip-angles can be used to identify under-steer and over-steer.

4.5 Slip Angle

Slip angle is the angle between the direction in which the tyre is pointing and the direction it is actually travelling in. It is the metric that essentially represents under-steering and over-steering. *"Under-steer is when you turn the wheel (into a corner) but your car goes straight-on, crashes into a tree and you die, and, over-steer is when you're driving on the same bit of road, the back of the car comes around, crash into a tree and you die."*, a very well-articulated explanation by Richard Hammond on Top Gear.

5 DASHBOARD

This section describes and documents the process of construction of the dashboard including requirements specification, dashboard design and creation of a preliminary dashboard.

A dashboard serves the purpose of providing an overview of key performance indicators (race metrics mentioned in section 4) that are relevant to a specific objective. In the project's context, the dashboard aims to help improve driver performance in virtual-racing. The dashboard summarizes and displays recorded data from Assetto Corsa, along with general session info and detailed data for each lap.

5.1 Requirements

Requirement Analysis for the dashboard comprised of constructing requirements from best practices and existing solutions in real-life motorsport, through stakeholder (supervisors) interviews and additionally borrowing and adapting requirements from past papers with similar aims [2, 18]. The requirements are constructed with a focus on ease-of-access and usability, to simplify the process for lap-data analysis.

5.1.1 *Functional Requirements.* **RQ1**

REQ 1 The system should display general session information like session duration, no. of laps and vehicle(s) driven.

REQ 2 The system should display telemetry information and key race metrics for each lap in session.

REQ 3 The system should allow users to upload files through the user interface for simple data-importing process.

REQ 4 The system should allow the users to compare statistics of multiple laps by overlaying graphs. (Inspired from Motec and SRT)

REQ 5 The system should display tyre properties (like temperature and wear) corresponding to each lap.

REQ 6 The system should allow users to navigate statistics over a portion of a lap. (Inspired from past-papers and professional tools)

REQ 7 The system should allow the user to correspond spikes/peaks in graphs to other statistics. (Inspired from multiple professional tools)

5.1.2 *Non-Functional Requirements.* **RQ2**

REQ 8 The system should maintain a consistent layout and theme across multiple pages.

REQ 9 The system layout should not be cluttered and allow usability for a range of users by focusing on clarity and categorization.

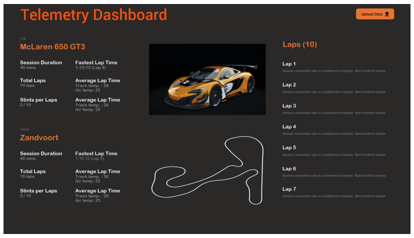
REQ 10 The system should be progressive and extensible to provide hassle-free feature additions..

REQ 11 The system should be compatible to data gathered for any combination of cars and tracks

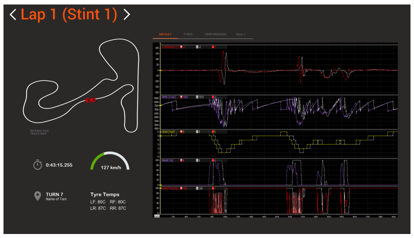
5.2 Design

The design process for the dashboard involved the following tasks:

- Construction of a lo-fi prototype describing layout, theme and features (**RQ3**)
- Design of development and technology architecture



(a) Session Overview - Home Page



(b) Lap Overview

Fig. 3. Design

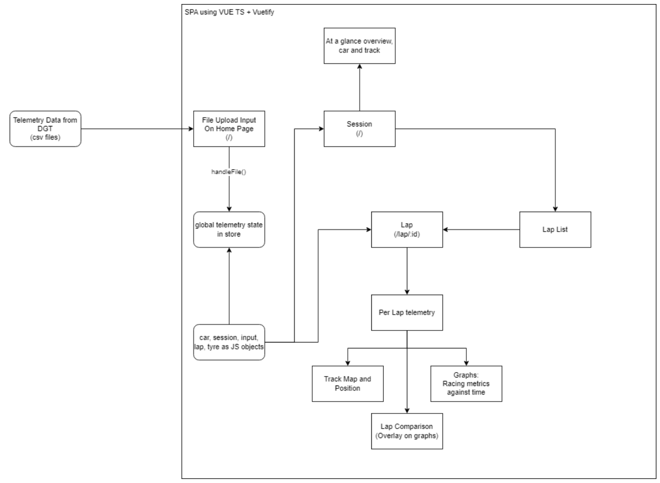


Fig. 4. Web Application Structure

The requirements that are meant to be realised through certain design choices are mentioned in parentheses following the design decision.

5.2.1 Lo-fi Prototype. The construction of the lo-fi prototype was revolved around realising the proposed requirements into tangible design features.

The lo-fi prototype was constructed using Justinmind, a prototyping and wireframing tool commonly used for designing web-applications and mobile apps. The prototype describes a two-page application consisting of a general home-page (see Figure 3a) which provides a general overview for the overall session, and a lap-overview page (see Figure 3b) that displays key performance indicators along with graphs for relevant race metrics.

The Home page illustration describes a simple 3-column starting page that serves as a starting point for the app. It displays general information such as the car and the track involved in the session and key metrics such as fastest-lap time and environmental conditions that are relevant in a global context for all information (**REQ 1**). Additionally, it displays a list of laps with clickable links that directs them to the lap-overview page for the respective lap.

The Lap overview page illustrates a page for each lap in a session highlighting key factors such as lap time, validity of lap while also visualising various race metrics against position on the track (**REQ 2**). This pages also envisions interactive graphing where each point on graph updates the left-hand side panel of the page which displays location, time and speed at that point (**REQ 7**). The graphs are divided into default categories: Basic, Performance and Tyres and additionally and option to create custom category with different graph compositions (**REQ 9**). Moreover, it was also envisioned (while not designed into the prototype) to allow users to compare statistics of other laps on this page (**REQ 4**).

5.2.2 Development architecture. Having identified only two pages with content and no real back-end, a single-page-application web-app design was selected for the dashboard. Vue 3 was the flavour of JavaScript (TypeScript) framework that was chosen for the project, it is a progressive web-development framework to design versatile user interfaces which provides flexibility for future extensions (**REQ 10**), and when coupled with Typescript provides quality code. As for styling and themes, Vuetify, a Vue-based customizable component library, was integrated into the project for quick layout and themes.

The Home-Page (Session Overview) serves as the entry point into the application, which at first load does not display anything except the title of the app and the upload button. Upon file upload, the information is retrieved from the global object that holds file data and rendered onto the home-page. More details are visualised in Figure 4.

5.3 Preliminary Dashboard

The development of the dashboard application was finalised in three iterations with each signifying implementation of multiple features as envisioned by the design and requirements (**RQ3**). The requirements meant to be realised by certain feature implementations are mentioned in the parentheses. The source-code for the dashboard is available on GitHub[1].

5.3.1 First Iteration. The first iteration dealt with constructing basic layout of the web-app as per the design and basic data-processing. This involved implementing the file upload (**REQ 3**) and processing data into a global object (which was achieved by transforming the data from the CSV files into a JavaScript object) that can be accessed by all components through a custom store. All relevant race metrics were extracted through the object by matching timestamps across different elements (all data processing is based on the format provided by the DGT tool [6]).

[1] https://github.com/SaDaT895/telemetry-dashboard

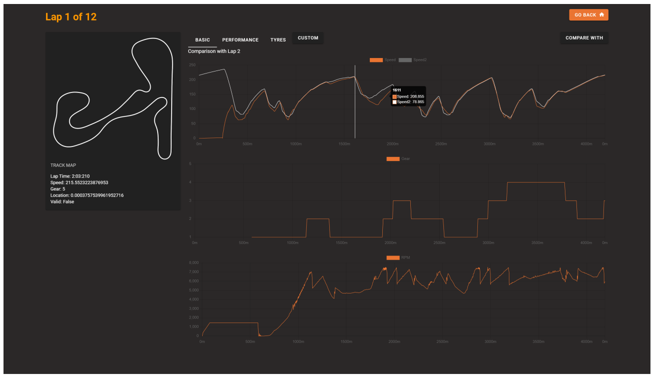


Fig. 5. Dashboard in Second Iteration

Additionally, this iteration oversaw the integration of Vuetify to customize the theme to match the basic design colours and scaffold the basic layout for the two pages (**REQ 8**).

5.3.2 Second Iteration. Within the second iteration, data visualization and core functionalities were implemented into the web-app.

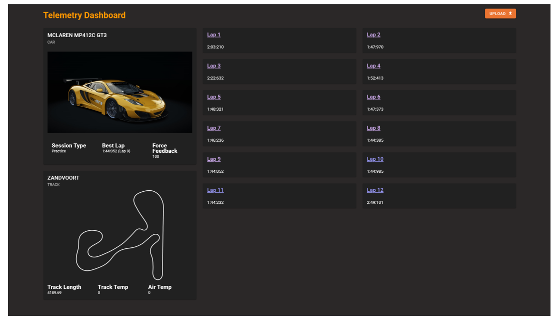
Data visualisation was implemented through the ChartJS library in the form of line charts. A crosshair and zooming extension to ChartJS was implemented for easy navigation of graphs for a part of lap (**REQ 6**). All the graphs are plotted against the length of the track, the datapoints for the x-axis are obtained by multiplying lap position element from the data (percentage of the circuit covered) and the length of the track (also available in the data). This provides a consistent and uniform axis for comparing laps head-on. Additionally, in-order to make the analysis less cluttered and complex, pre-sets for graphs were programmed into the lap-page with tabs (as shown in the design) indicating sets of graphs: Basic (Speed, RPM, Gear etc.), Performance(Throttle, Brake Pedal, Steering) and Tyres (**REQ 9**).

The overlay feature was also achieved in this iteration by dynamically adding an extra dataset to the graph which renders the data points from other lap onto the current graph (see white line graph in Figure 5) (**REQ 4**). This was realised through a drop-down menu on the Lap Overview Page for usability and easy analysis.

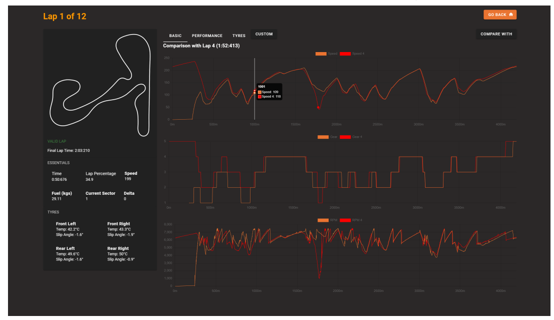
5.3.3 Final Iteration. The final iteration oversaw implementation of more desirable functionalities and improvement of existing features from the second iteration.

An interactive module over the graphs was implemented into the lap-page through which clicking on a point updates the previously static placeholder information on the left-hand side of the page (card with track map) such as lap-time and location at that point (See Figure 6b) (**REQ 7**). The module facilitate users to pin-point moments of spikes and fluctuations and correspond them to not only lap-time but also other statistics like speed, lap-delta and tyre conditions.

Sectors were also introduced in this iteration to fine-tune the granularity from 'laps' to 'sectors', which was achieved through additional data-processing. The change in granularity allows users to not deal with lap as a whole but have an underlying constituent for further recognition.



(a) Session Overview - Home Page



(b) Lap Overview

Fig. 6. Final product

The overlay features ware revamped into a multi-lap comparison tool to allow for comparison of more than two laps (or sectors) simultaneously, this allows for more informative analysis situations such as: comparing two laps to the fastest lap. The dropdown menu for the comparison was replaced by a select-input for further usability.

6 USER TESTS AND FEEDBACK

This section documents the process and results of user-tests and interviews for the validation of the final product.

6.1 User Tests

In order to gather feedback and validate requirements moderately-experienced to experienced drivers were invited for a test-run of the app. This was an online process, wherein a stable version of the web-app was hosted temporarily on a URL which was shared with the participants through e-mail/Discord along with a survey form for feedback. Additionally, some previously collected data from the DGT tool (CSV files) were also provided to the participants for a more natural user-test.

The participants were then expected to upload the files and utilize the app in their own time to provide valuable feedback. This was a guided process, a step-by-step guide (see Appendix A) for the user-test was attached in the emails/messages sent. Some of the expected tasks included:

- Navigating to multiple lap page and back to home-page
- Switching the category of the graphs on the lap-page
- Overlaying other lap data
- Removing the overlay data

Table 1. Table captions should be placed above the table

	1	2	3	4	5
Usability	-	-	-	40%	60%
Functionality	-	20%	-	60%	20%
Potential	-	-	-	60%	40%
Aesthetics	-	-	20%	20%	60%

- Switching overlays to other lap
- Zooming in graphs to pan out spikes
- Clicking individual data-points to see general information

Based on their experiences and findings, the participants filled out a survey form with questions about overall usability of the dashboard along with opinions about aesthetics and layout (see Appendix B.1). The survey comprised of both quantitative and qualitative questions, with the former presented with a 5-level Likert scale (for e.g. very dissatisfied to satisfied) for response.

6.2 Evaluation

The main results from the survey response (see Appendix B.2) are provided in table 1 and summarized further in the following subsections.

6.2.1 Usability. Avg. score: **4.6**

According to the results, majority of the participants were very satisfied with the usability of the dashboard while only some participants were somewhat satisfied. Additional comments included praise for the intuitive UI and the interactive graphs, and suggestions such as: custom-graph layouts and the ability to focus (full-screen) on a graph. A few participants also indicated that they prefer the simple structure of the dashboard over the complex user-interface of professional-tools.

6.2.2 Functionality. Avg. score: **3.8**

All except one participants agreed that the dashboard has all relevant metrics and features needed for a sim-racer to improve his/her performance, including one participant who strongly agreed over the completeness of the dashboard. Additional comments included suggestions for additional lap-information on the home-page, synchronised zoom-in for graphs, ability to compare individual sessions, introduction of a delta graph when comparing laps, implementation of side-load and g-forces. Furthermore, the interactive graph-module was voted as the best feature of the app by all participants.

6.2.3 Potential to increase performance. Avg. score: **4.4**

All participants agreed over the dashboard's potential to enhance their sim-racing performance with many stating that they could see themselves using it for their sim-racing sessions.

6.2.4 Aesthetics. Avg. score: **4.4**

When asked to rate the aesthetics of the dashboard, majority of the participants provided a 5 out of 5 score, with many complementing the sleek design and the dark colour-scheme.

7 CONCLUSION

The telemetry dashboard system developed as per the design proposed was proven to be a valuable software to provide easier data-analysis tools to the non-professional echelon of the sim-racing community. With less-complex data visualisations and usability features, the product provides simplicity and ease-of-use that may lack in professional racing-telemetry options.

The construction of the dashboard was based around the functional and non-functional requirements proposed in subsection 5.1. The proposed requirements were an amalgamation of features in professional tools, dashboard design theory and input from supervisors. The functional requirements focused on usability values and features, while the non-functional requirements described a simplicity in the layout along with flexibility of the product.

The requirements were realised through elaborate design and development phases, with certain design choices and feature implementations completely based around one requirement. Thus, both the lo-fi prototype and the dashboard serve as artefacts for **RQ3**.

Results from the user-test survey include high score for usability and above-average score for the functionality of the dashboard, indicating successful realisation of functional requirements. Additionally, survey also concluded that most users feel confident in the dashboard's ability to provide insight into their driving style and help improve performance.

7.1 Limitations

While the dashboard serves as a viable proof-of-design for lap analysis and lap comparison, it lacks design for comparing individual sessions and/or comparing between two drivers. Session comparison might be valuable for small-teams to analyse performance statistics among multiple drivers. Additionally, the dashboard is designed around the data from Assetto Corsa, therefore it might not be exactly applicable to other simulators wherein they may have less or more data available.

Due to time-constraint, user-test evaluation was conducted on a very-small sample (5) of mostly moderately-experienced drivers. This may not fully test the viability of the product as there is a lack of input from small-sized esports teams and individual competitive racers. Therefore, the results of the survey cannot be generalised to the whole of intended user-base.

7.2 Future Work

The dashboard provided by this research is a preliminary version of itself, therefore, there is much scope for future work and improvement.

As mentioned in subsection 7.1, the dashboard design lacks the ability for comparing sessions. Extending the design to include comparison of sessions can be valuable for many users to compare between different drivers and gain insights on their deficit.

Additionally, smoothness statistics such as throttle smoothness, steering smoothness etc. can be introduced to provide further performance insights to the user. Finally, for further ease-of-access, the design can be extended with track-location visualisation to pinpoint exact location on the track corresponding to the data.

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A USER-TEST

Welcome to the user-test for the preliminary dashboard for Assetto Corsa. The dashboard can be found at: (temporary hosted URL via ngrok). Keep in mind, this is not the final product. This serves as a proof-of-design.

To start the user-test:

(1) Navigate to the above-mentioned URL (it might give you some warning since I'm using a free plan on ngrok)
(2) Download the files from: (Google Drive link)
(3) Upload the files in the web-app (select all files at once)

After the page-load, discover the app on your own accord or follow the recommended steps below:

(4) Navigate to a lap-page
(5) Switch the categories of the graphs
(6) Overlay data from other graph
(7) Switch overlay to other lap
(8) Remove the overlay data entirely
(9) Zoom in on graphs (mousewheel or touchpad) to pan out spikes
(10) Click on graph area to see dynamic information

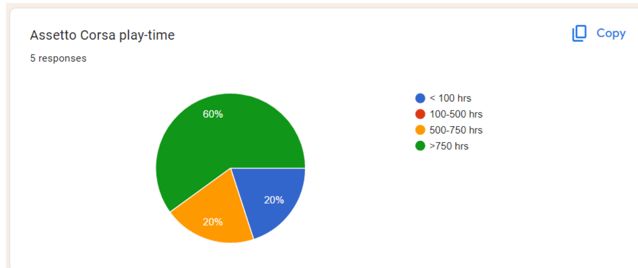
Play around the app a little-more if you'd like or move ahead to the feedback survey. Survey link: (link to survey)

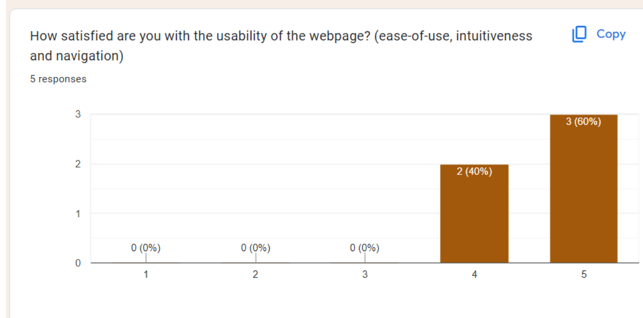
B EVALUATION

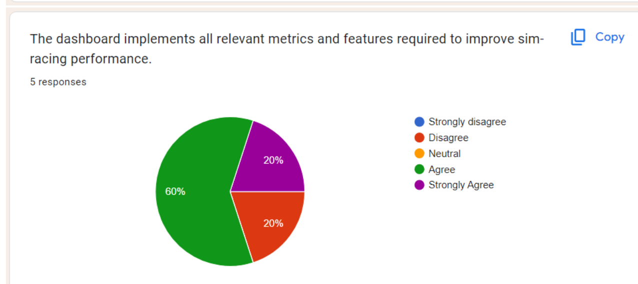
B.1 Survey

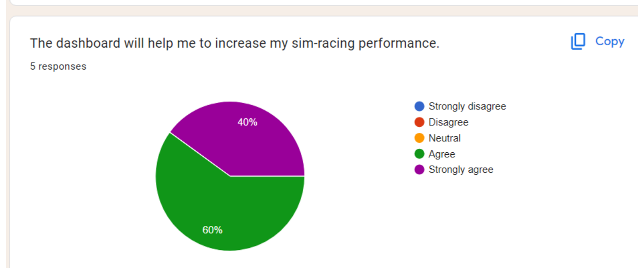
The survey conducted via Google Forms is available at this link.

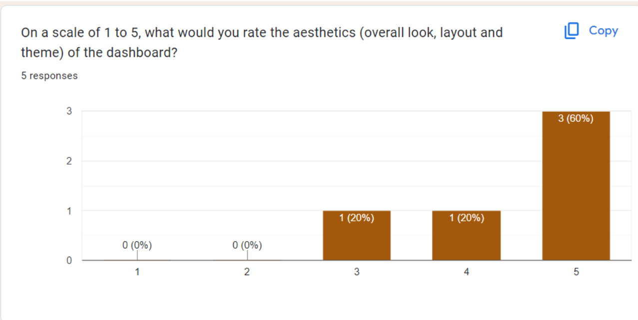
B.2 Survey response

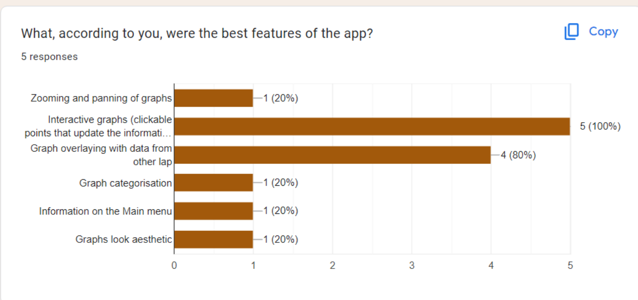












Overall impression and additional comments:

- For further improvement, add more features and customizable graphs. Live telemetry features. Additional important lap information on the home page.
- couple of things: - tyres not working - when using the interactive part of the graph, you cannot see the location on the circuit map (would be a very good feature to implement) - When zooming in one 1 graph, the rest should zoom with it so that the alignment of the charts stays the same, that way you can keep comparing the data to each other (important when comparing things like steering angle and downshifts etc, to see what 'caused' the time loss)
- Quite a fan of this! A great idea for a web-based app that would provide tangible benefits towards my racing pursuits. I like the design and it is easy to navigate. I quickly sorted out how to use all features, like comparison / zooming in / clicking to bring up more data in the sidebar. There are a couple of things that I would love to see as an experienced user; the tire data tab would have been quite interesting. Side-forces, slip angle (which is implemented in the sidebar already, nice), g-force, lateral load. Aero data / ride height would also have been interesting. Perhaps even a real-time tracker or dot of some kind on the track map so you can follow along with the cursor in real time. This may be more difficult than what it's worth to implement, but for beginners it would be far easier to follow a visual cursor on the track itself as you move through the data. These are all things I can already see and use in other purpose-built applications. But, for someone who's just starting to implement telemetry into their racing, this would be a great starting point and would be useful for them far into the future. The data displayed is still certainly useful for me, someone who has been using telemetry for many years and is relatively familiar with the usual applications (despite not possessing a degree in mech. eng.).
  Overall, well done! Instead of using a somewhat outdated, purpose built application that would have to be loaded on all target machines, this allows anyone with the knowledge to pull telemetry data from the simulator quick access to visual data that would likely be immediately useful. Making telemetry accessible to more people is a great positive in my opinion.
- very sleek aesthetic of dashboard, good deeper info when clicking on graphs. comparing graphs is a must and really useful for improving lap-times, maybe introduce a delta graph when comparing laps.
- Very detailed and professional